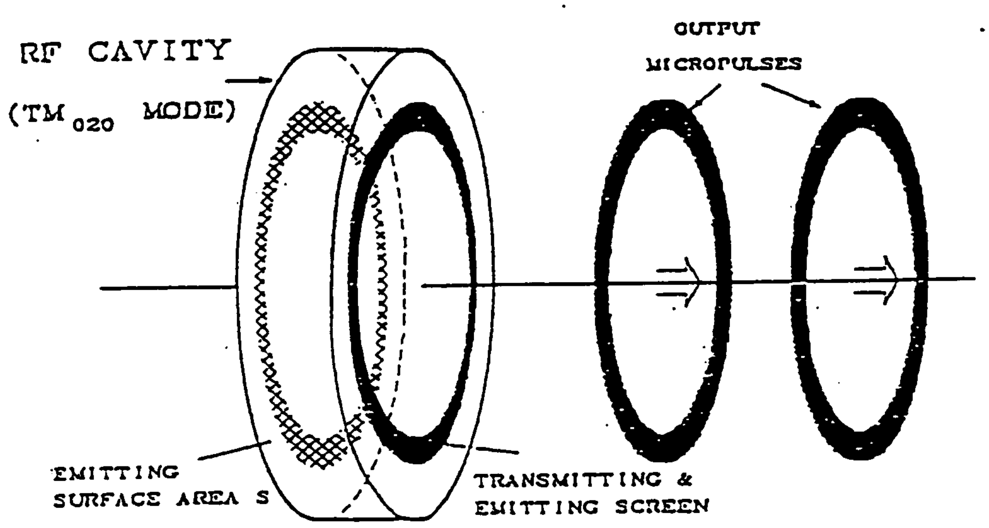

RF CAVITY
(TM$_{020}$ MODE)
OUTPUT MICROPULSES
EMITTING SURFACE AREA S
TRANSMITTING & EMITTING SCREEN

FIGURE 1

TM-020 Mode Cavity with Inner Cylinder

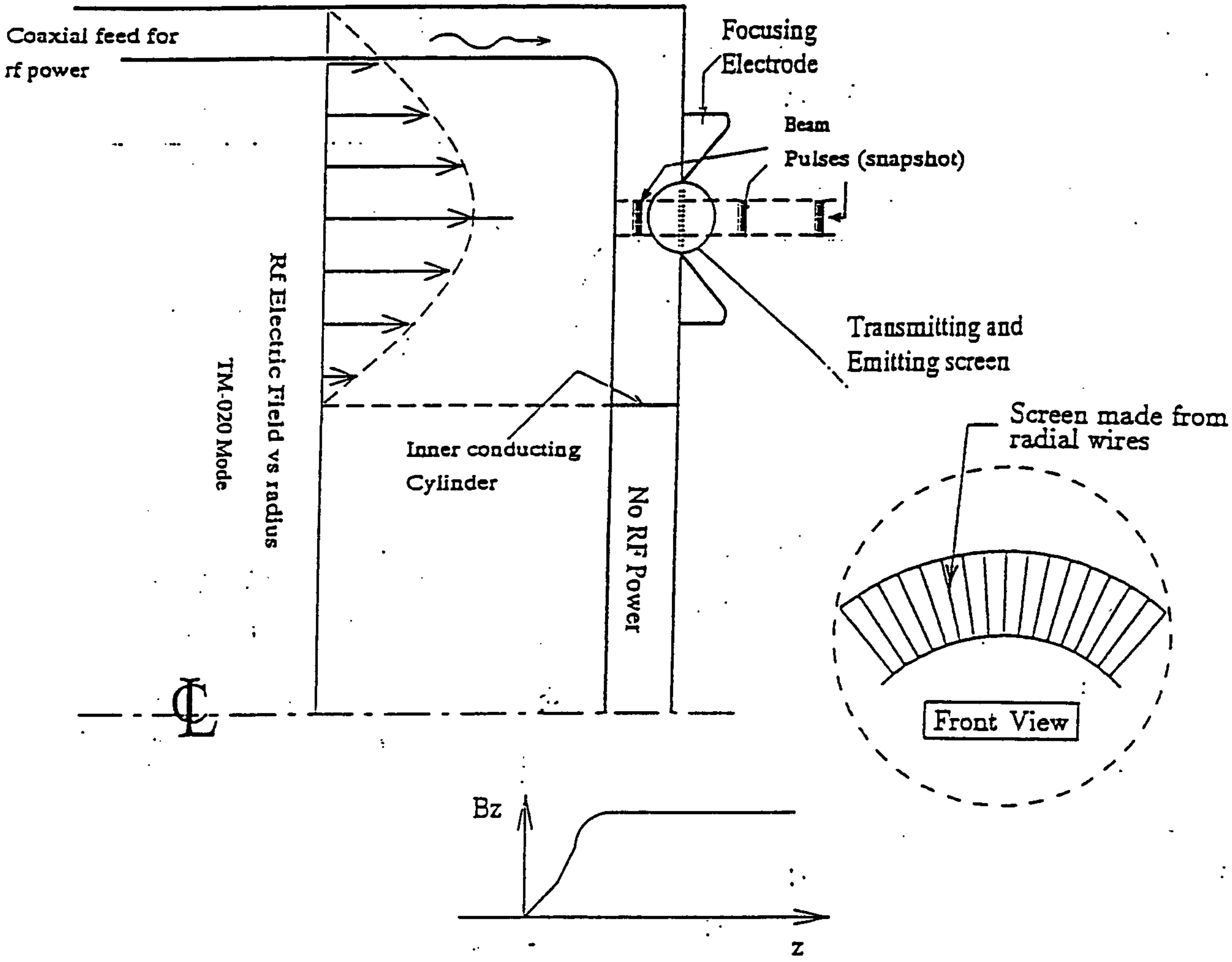


FIGURE 2

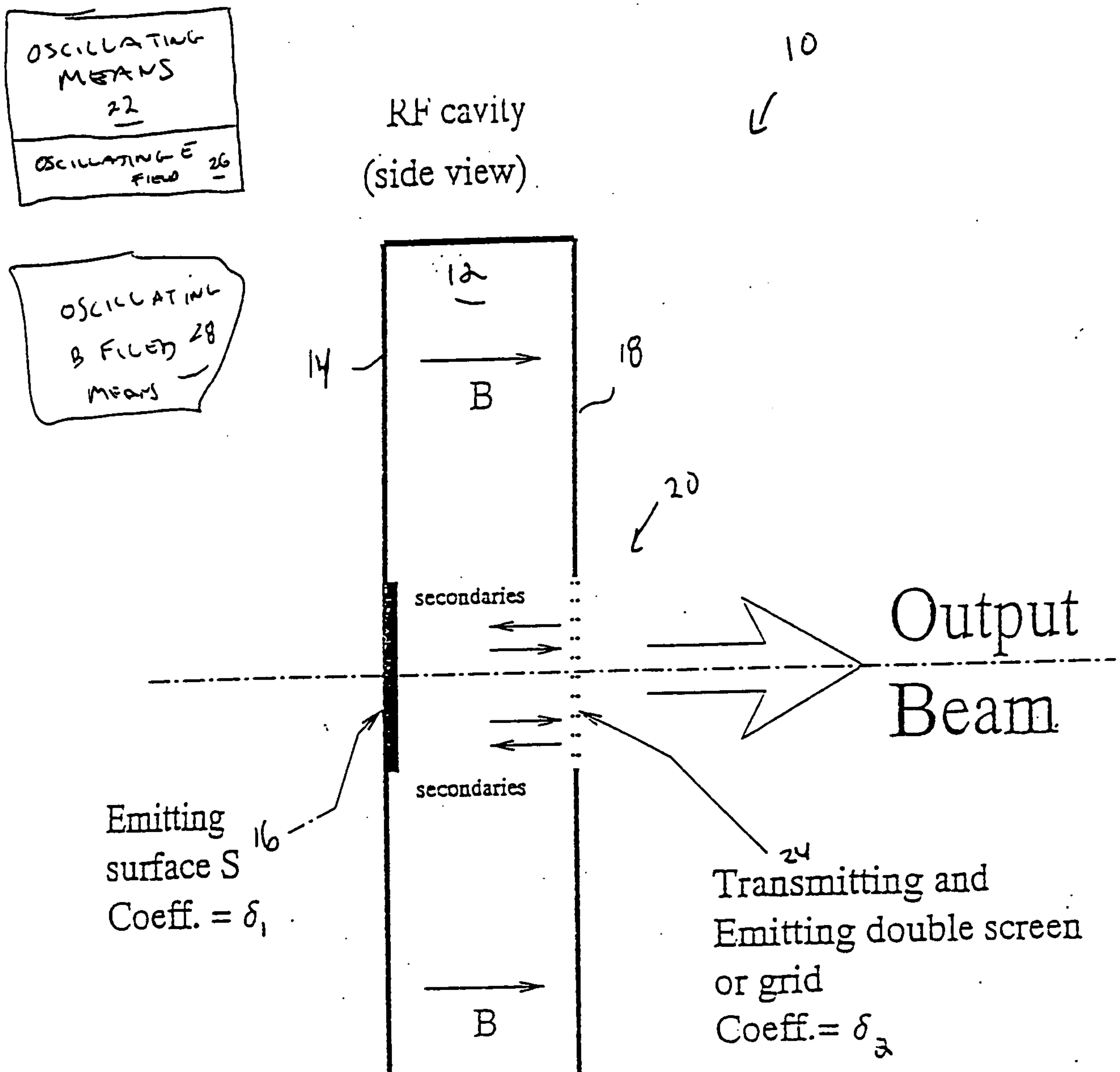

OSCILLATING MEANS 22
OSCILLATING E FIELD 26
OSCILLATING B FIELD MEANS 28
RF cavity (side view)
10
12
14
18
B
20
secondaries
Output Beam
secondaries
Emitting surface S Coeff. = δ_1
16
24
Transmitting and Emitting double screen or grid Coeff.= δ_2
B

FIGURE 3

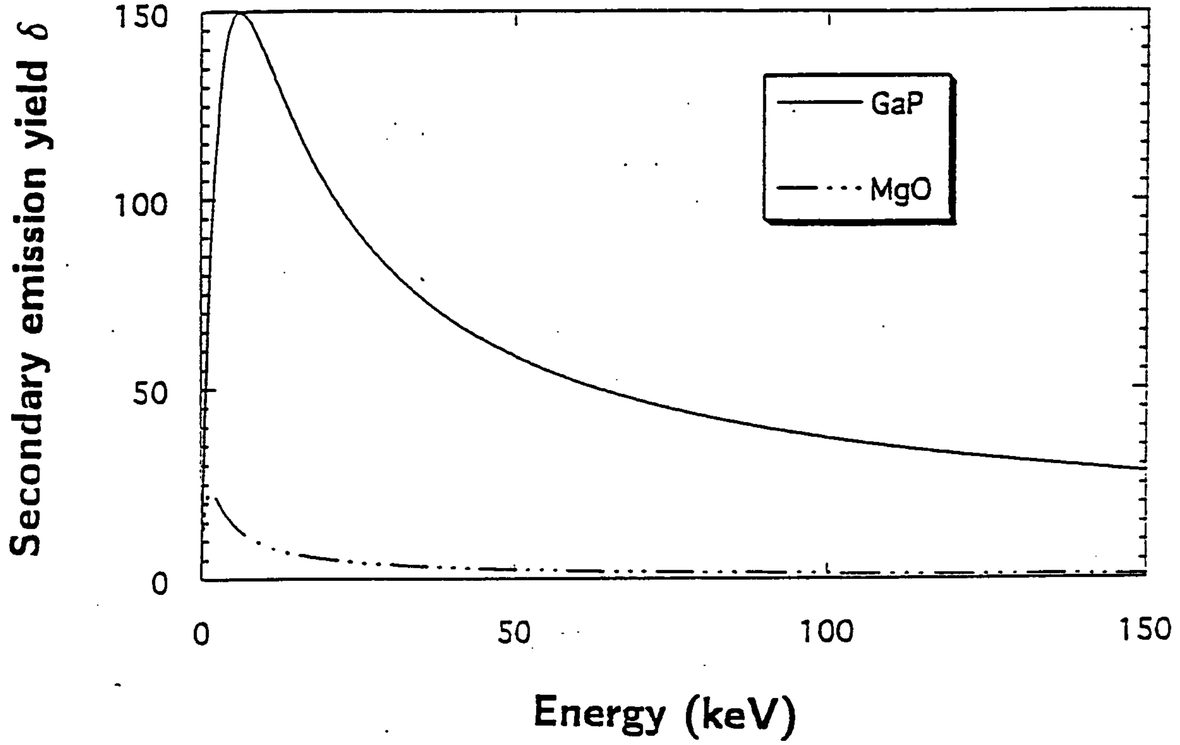

Secondary emission yield δ
150
100
50
0
0
50
100
150
Energy (keV)
GaP
MgO

FIGURE 4

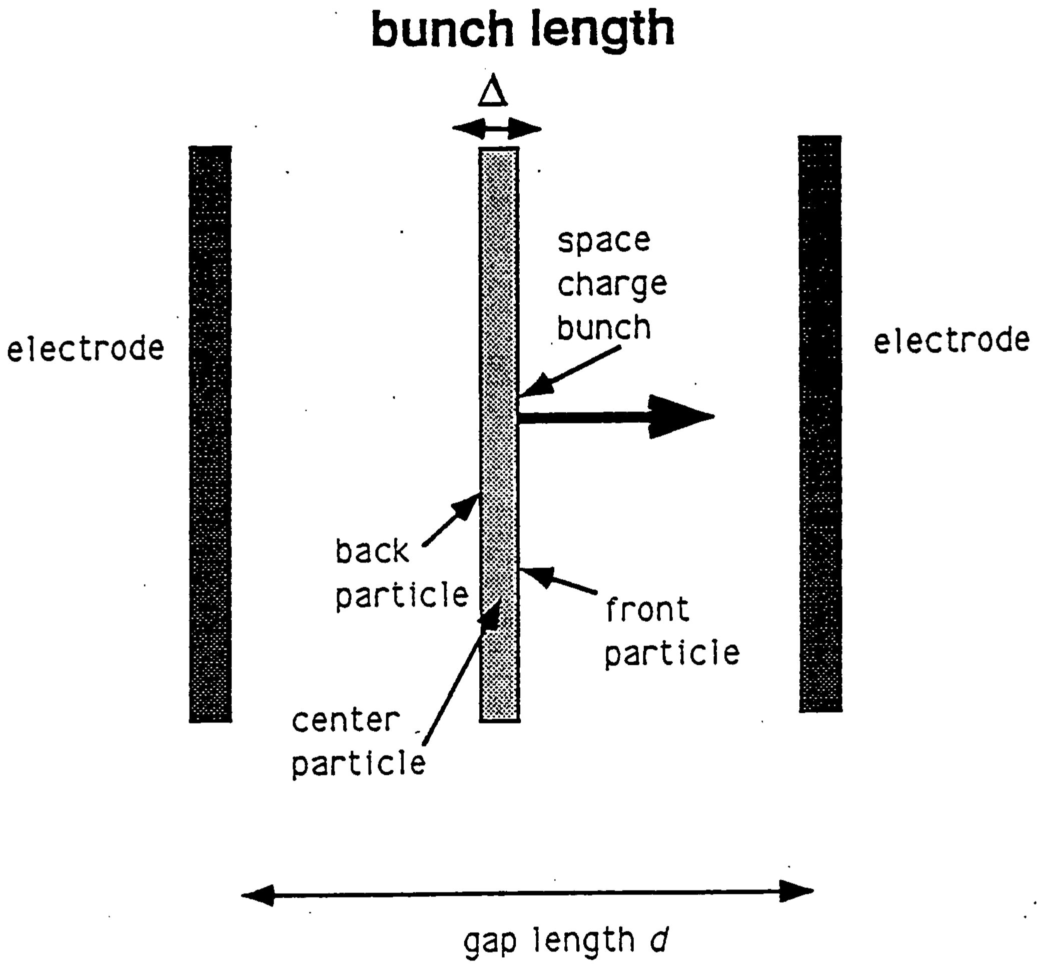

bunch length
Δ
space
charge
bunch
electrode
electrode
back
particle
front
particle
center
particle
gap length *d*

FIGURE 5

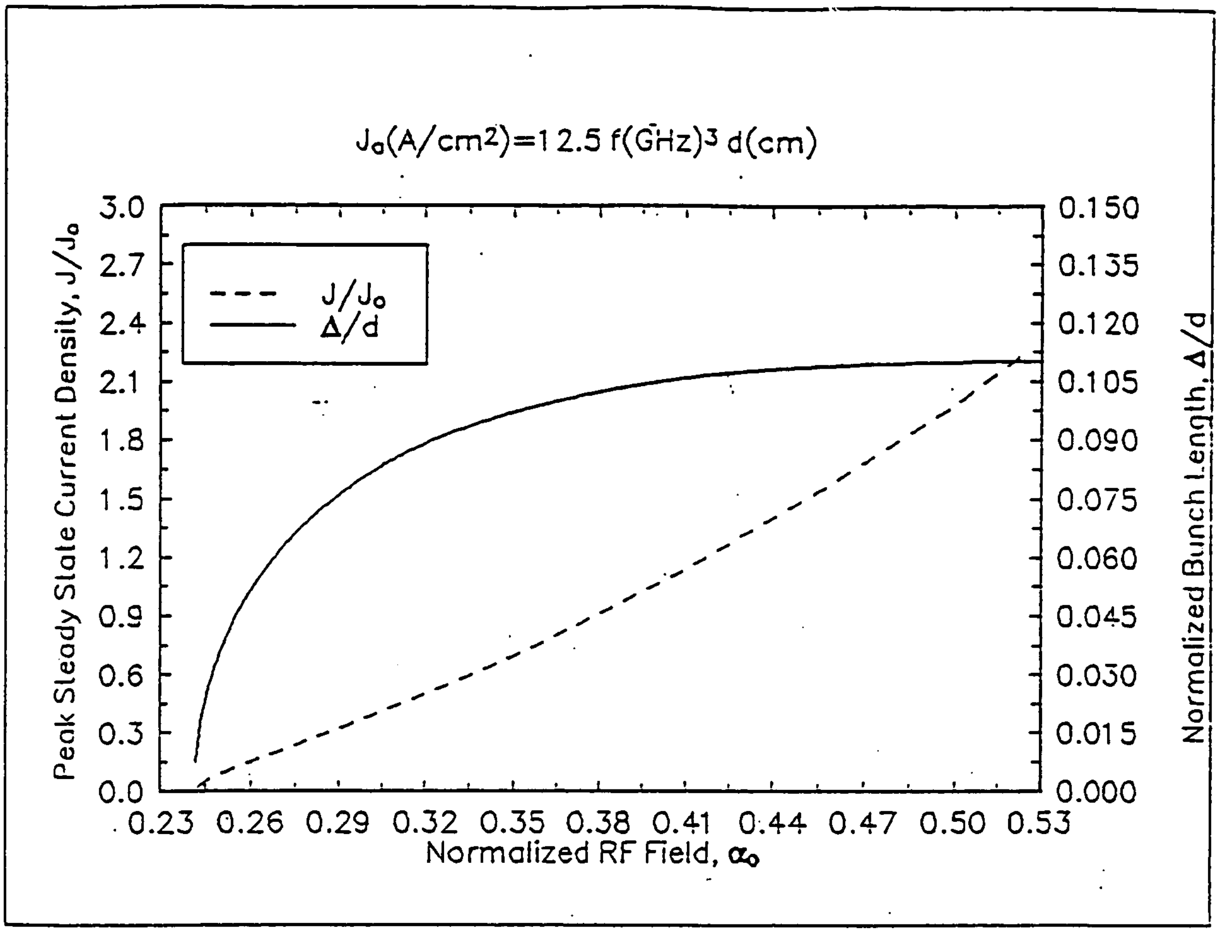

$J_o(A/cm^2)=12.5\,f(GHz)^3\,d(cm)$
J/J_o
Δ/d
Peak Steady State Current Density, J/J_o
Normalized Bunch Length, Δ/d
Normalized RF Field, α_o
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0.150
0.135
0.120
0.105
0.090
0.075
0.060
0.045
0.030
0.015
0.000
0.23
0.26
0.29
0.32
0.35
0.38
0.41
0.44
0.47
0.50
0.53

FIGURE 6

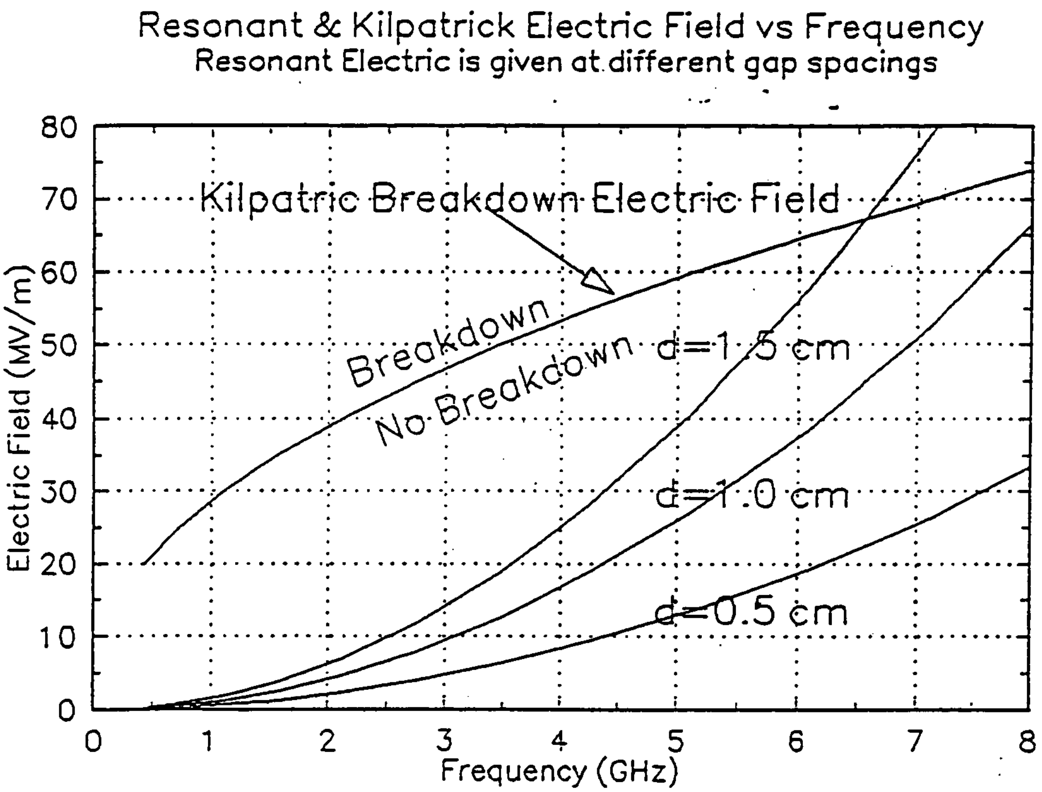

Resonant & Kilpatrick Electric Field vs Frequency
Resonant Electric is given at different gap spacings
Kilpatric Breakdown Electric Field
Breakdown
No Breakdown
d=1.5 cm
d=1.0 cm
d=0.5 cm
Electric Field (MV/m)
80
70
60
50
40
30
20
10
0
Frequency (GHz)
0
1
2
3
4
5
6
7
8

FIGURE 7

1.3 GHz, xy plot

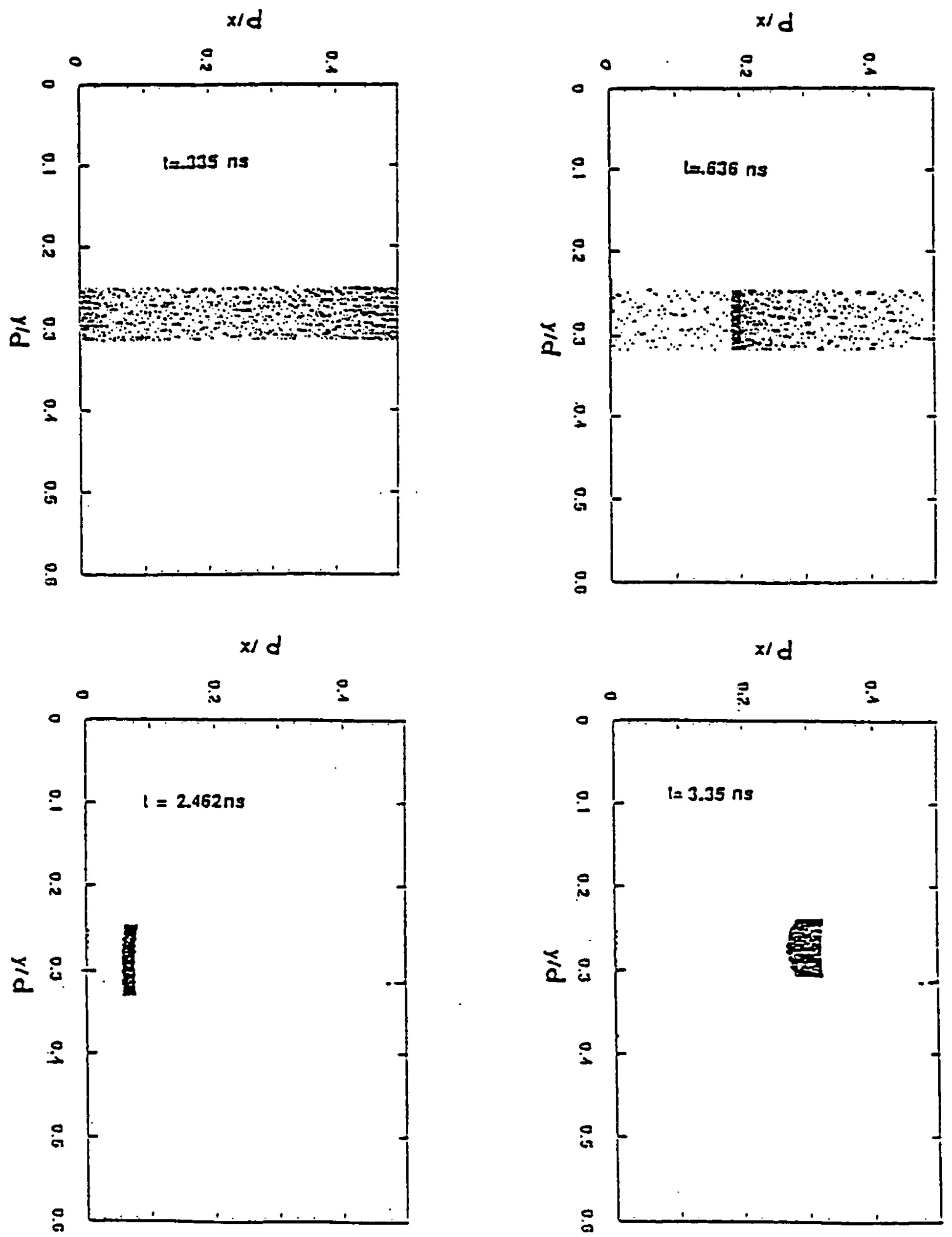


FIGURE 8

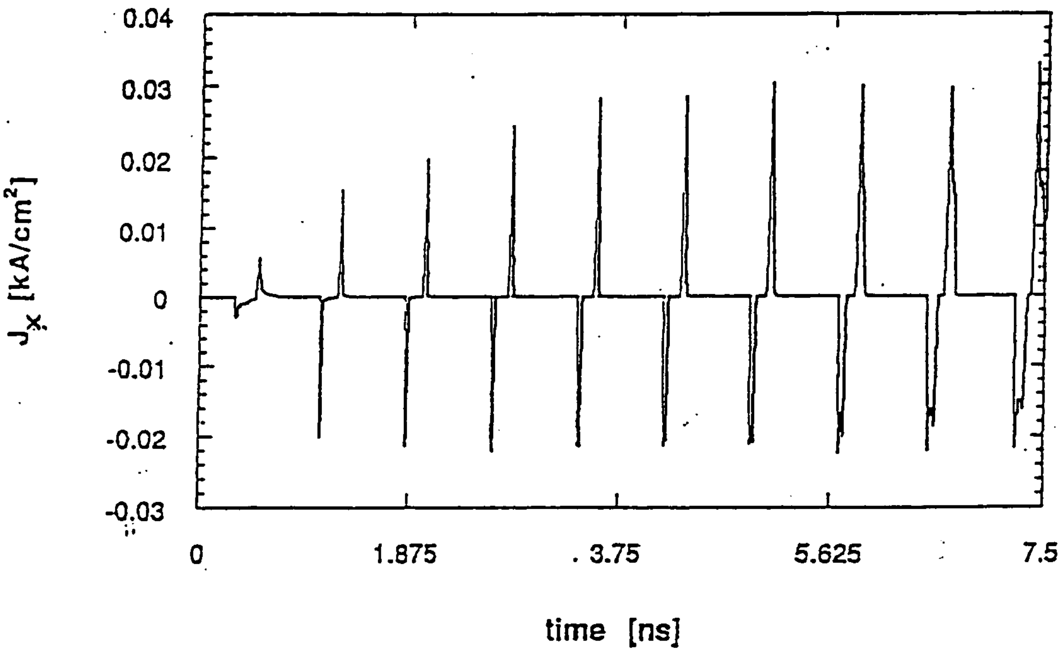


FIGURE 9

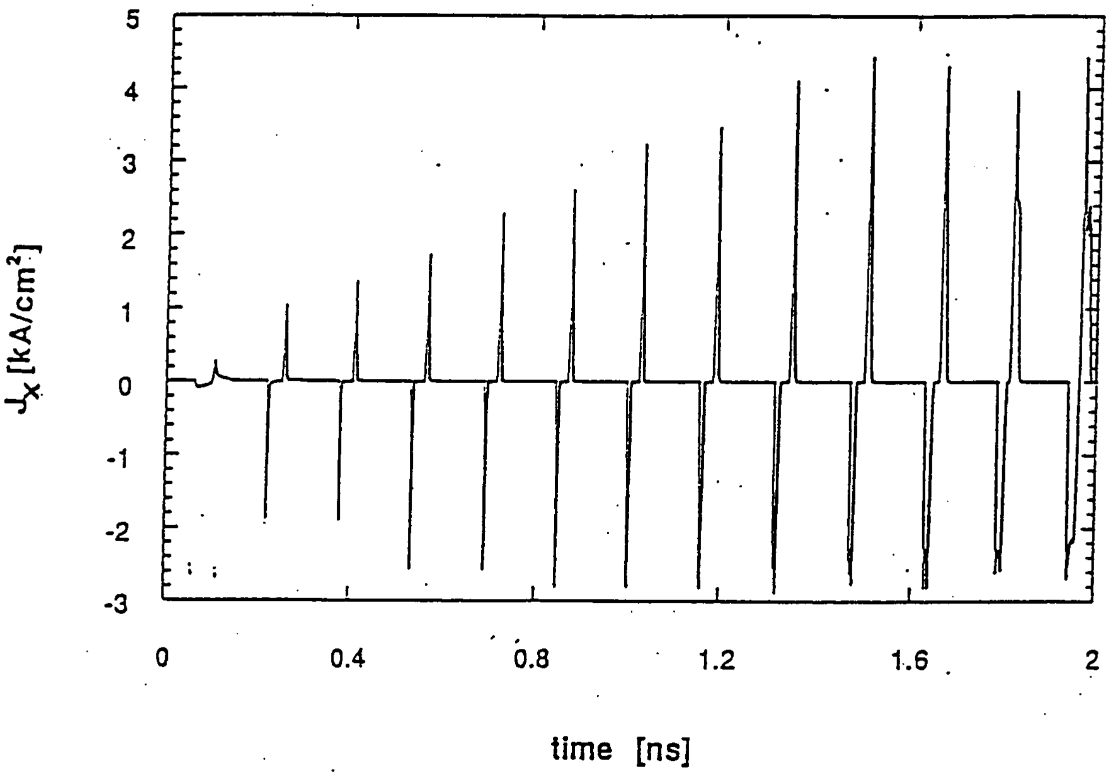


FIGURE 10

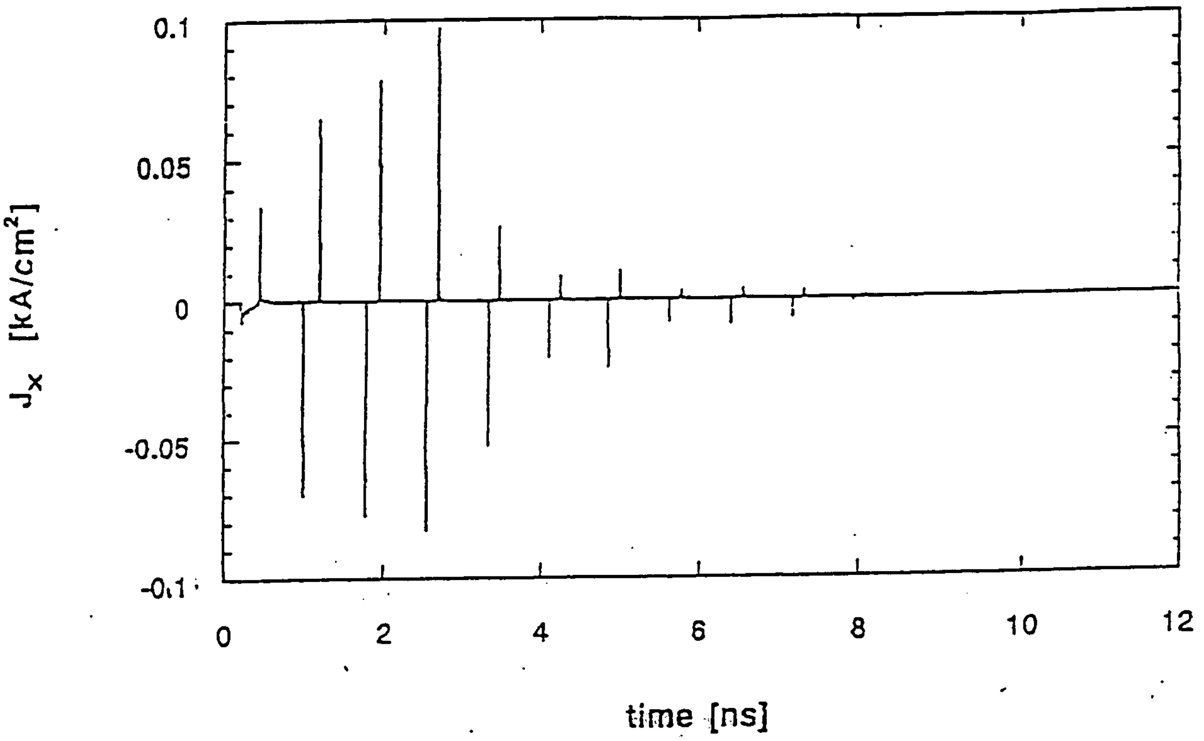


FIGURE 11

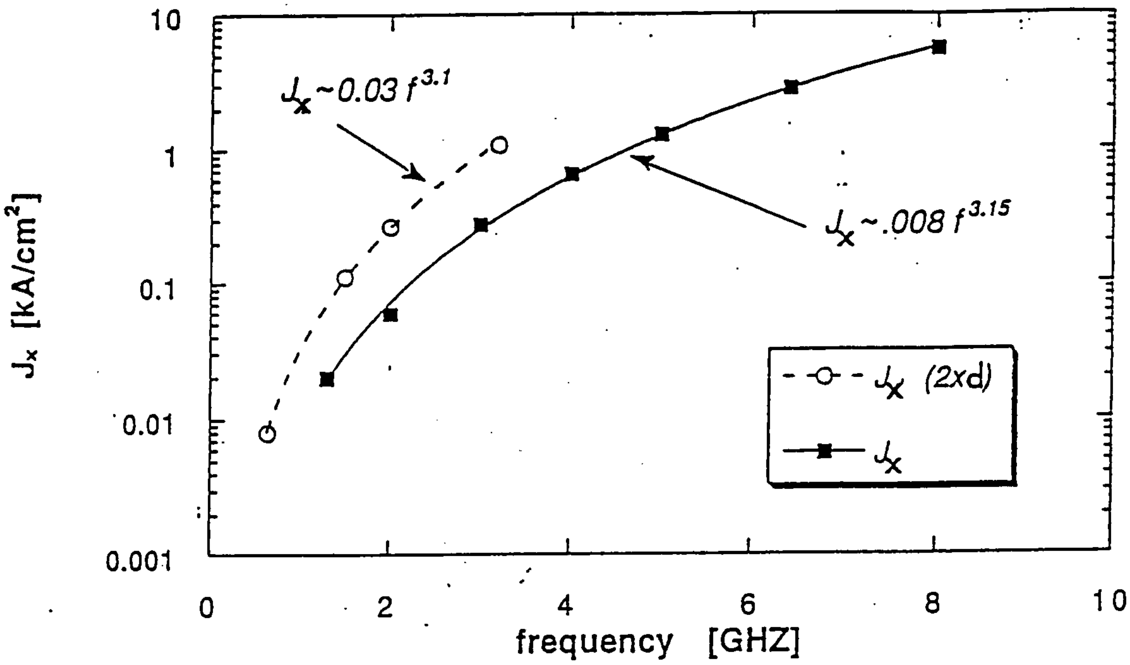

$J_x \sim 0.03 f^{3.1}$
$J_x \sim .008 f^{3.15}$
J_x (2xd)
J_x
J_x [kA/cm^2]
10
1
0.1
0.01
0.001
0
2
4
6
8
10
frequency [GHZ]

FIGURE 12

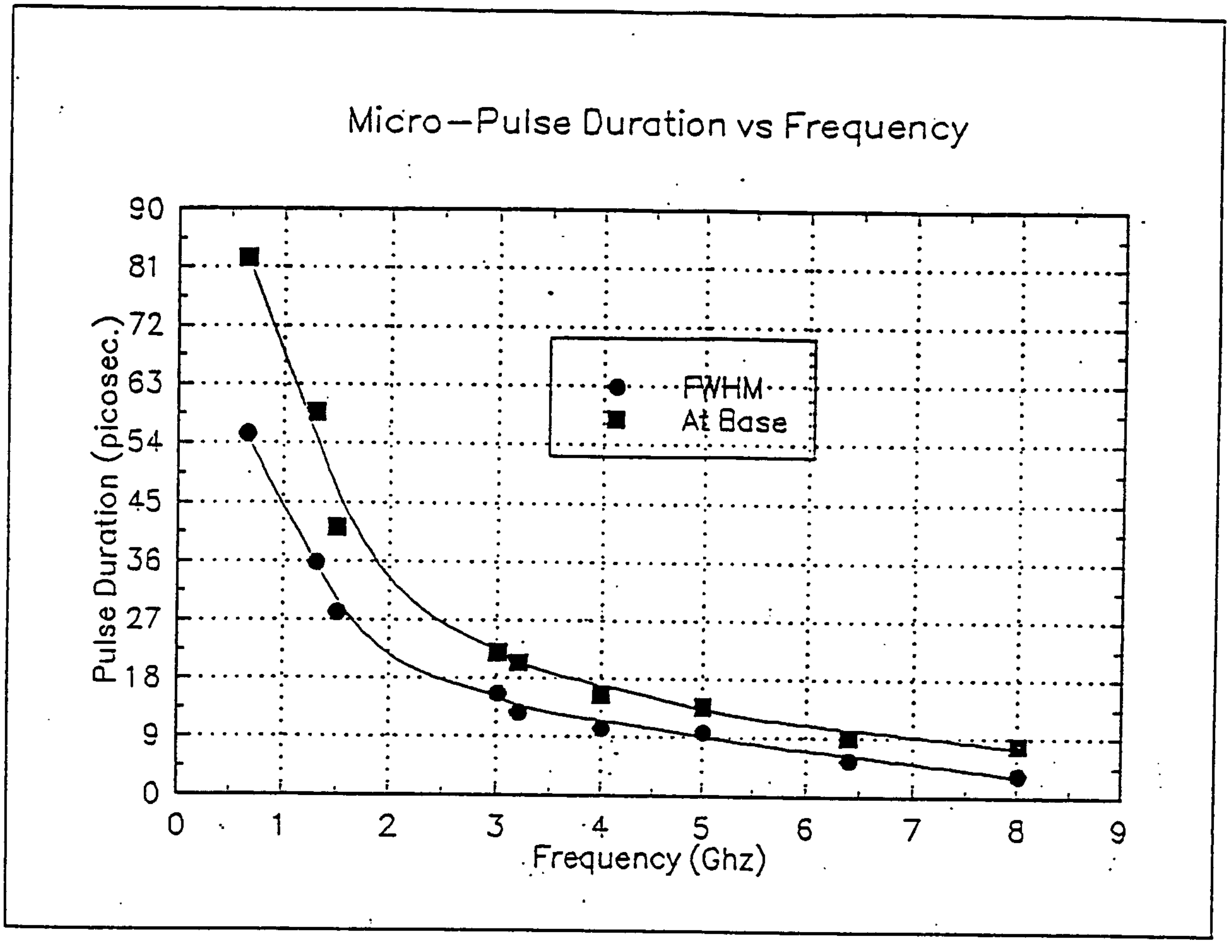

Micro—Pulse Duration vs Frequency
Pulse Duration (picosec.)
90
81
72
63
54
45
36
27
18
9
0
0
1
2
3
4
5
6
7
8
9
Frequency (Ghz)
● FWHM
■ At Base

FIGURE 13

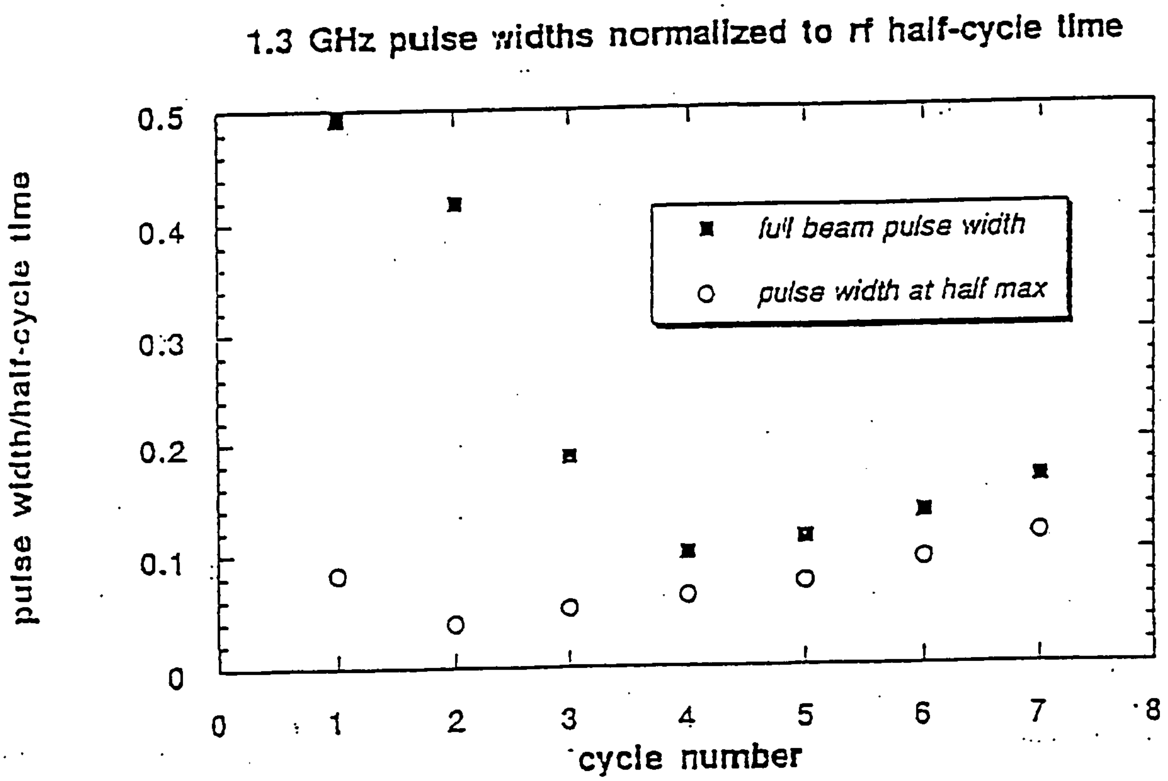

1.3 GHz pulse widths normalized to rf half-cycle time
pulse width/half-cycle time
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
cycle number
full beam pulse width
pulse width at half max

FIGURE 14

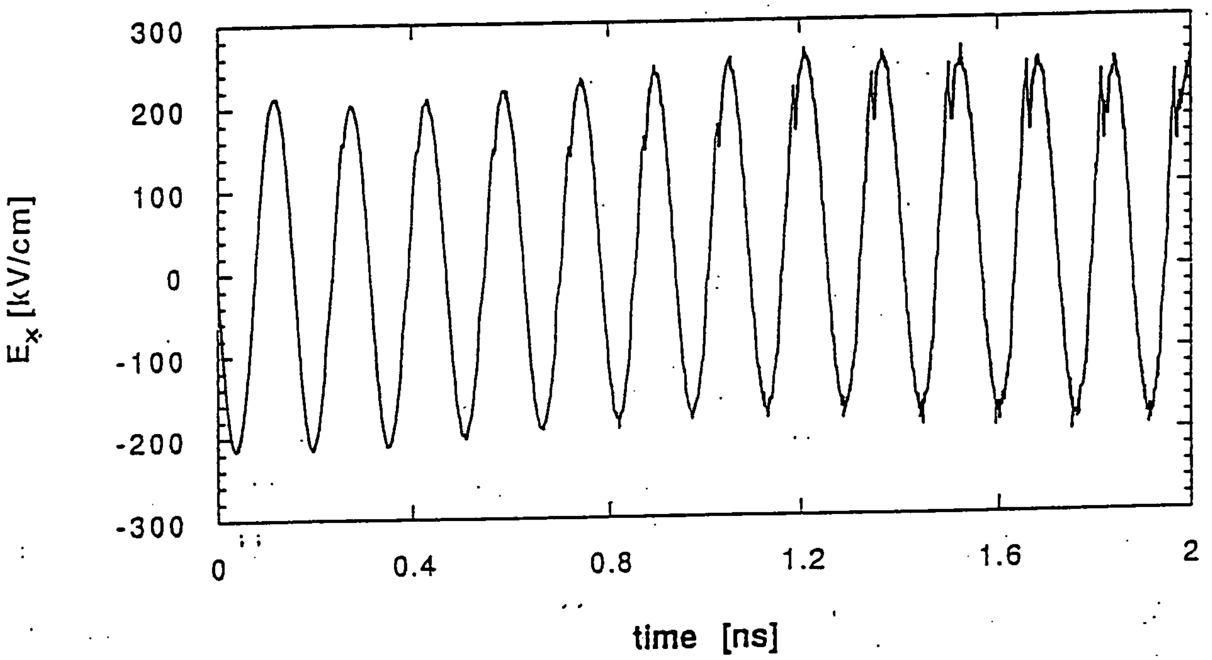
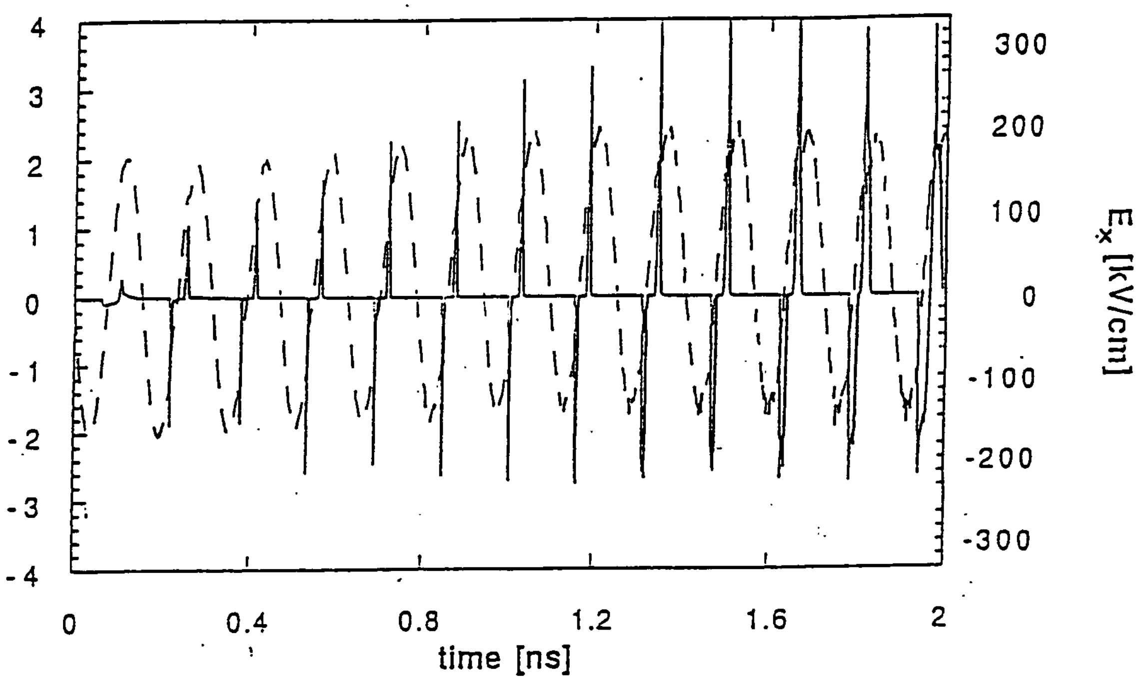


FIGURE 15



4
3
2
1
0
-1
-2
-3
-4
J_X [kA/cm^2]
300
200
100
0
-100
-200
-300
E_x [kV/cm]
0
0.4
0.8
1.2
1.6
2
time [ns]

FIGURE 16

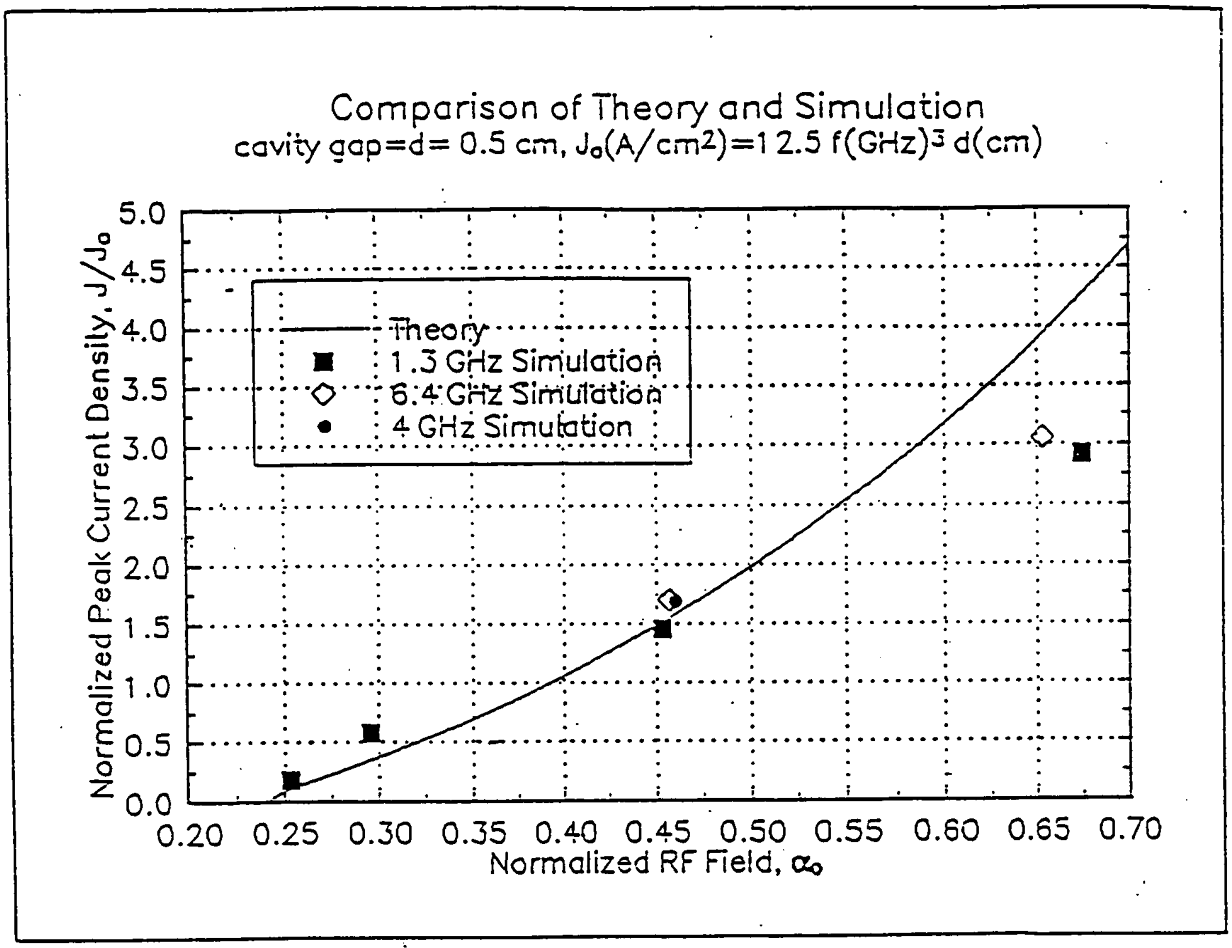

Comparison of Theory and Simulation
cavity gap=d= 0.5 cm, J₀(A/cm2)=12.5 f(GHz)³ d(cm)
Normalized Peak Current Density, J/J₀
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
Normalized RF Field, α₀
Theory
1.3 GHz Simulation
6.4 GHz Simulation
4 GHz Simulation

FIGURE 17

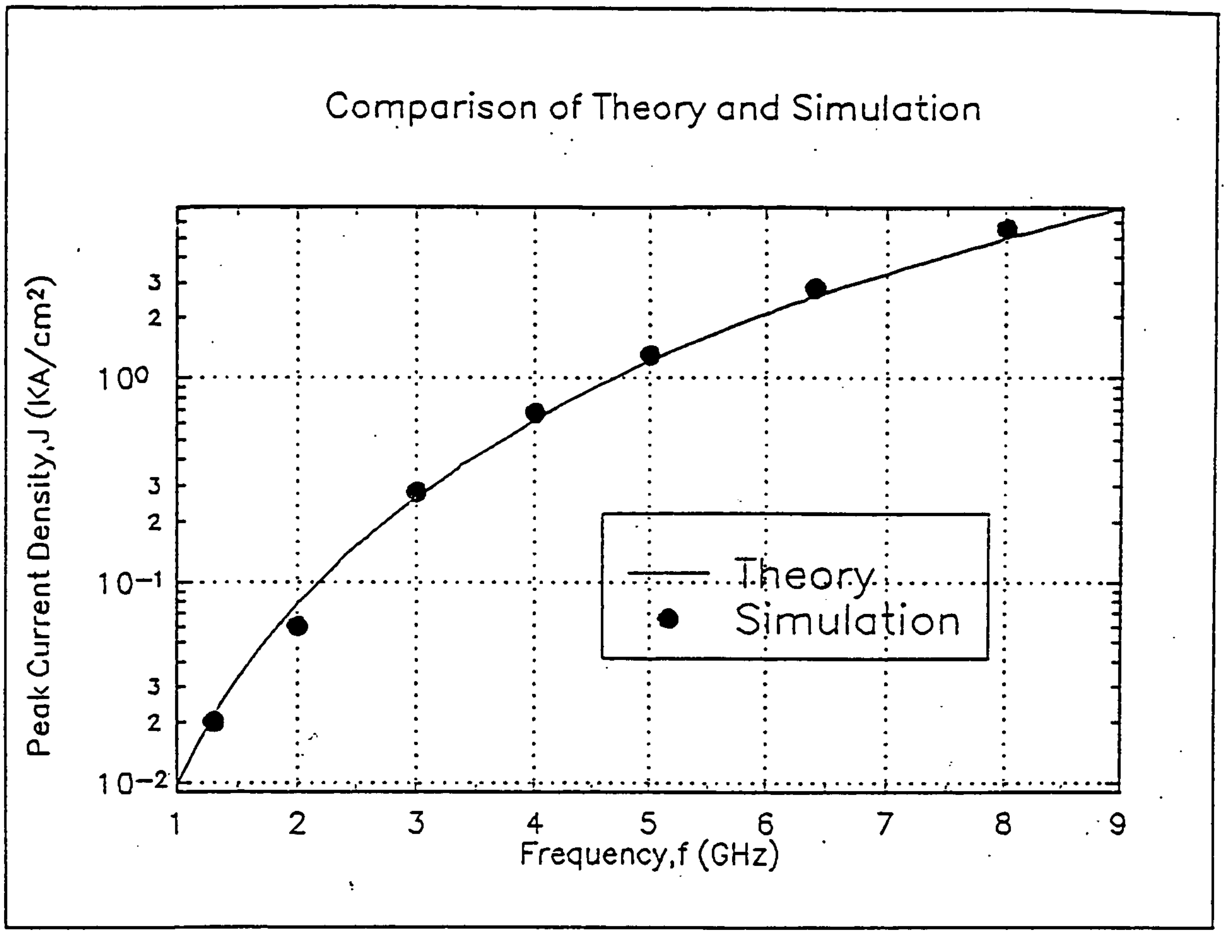

Comparison of Theory and Simulation
Peak Current Density,J (KA/cm²)
10⁰
10⁻¹
10⁻²
3
2
Frequency,f (GHz)
1
2
3
4
5
6
7
8
9
Theory
Simulation

FIGURE 18

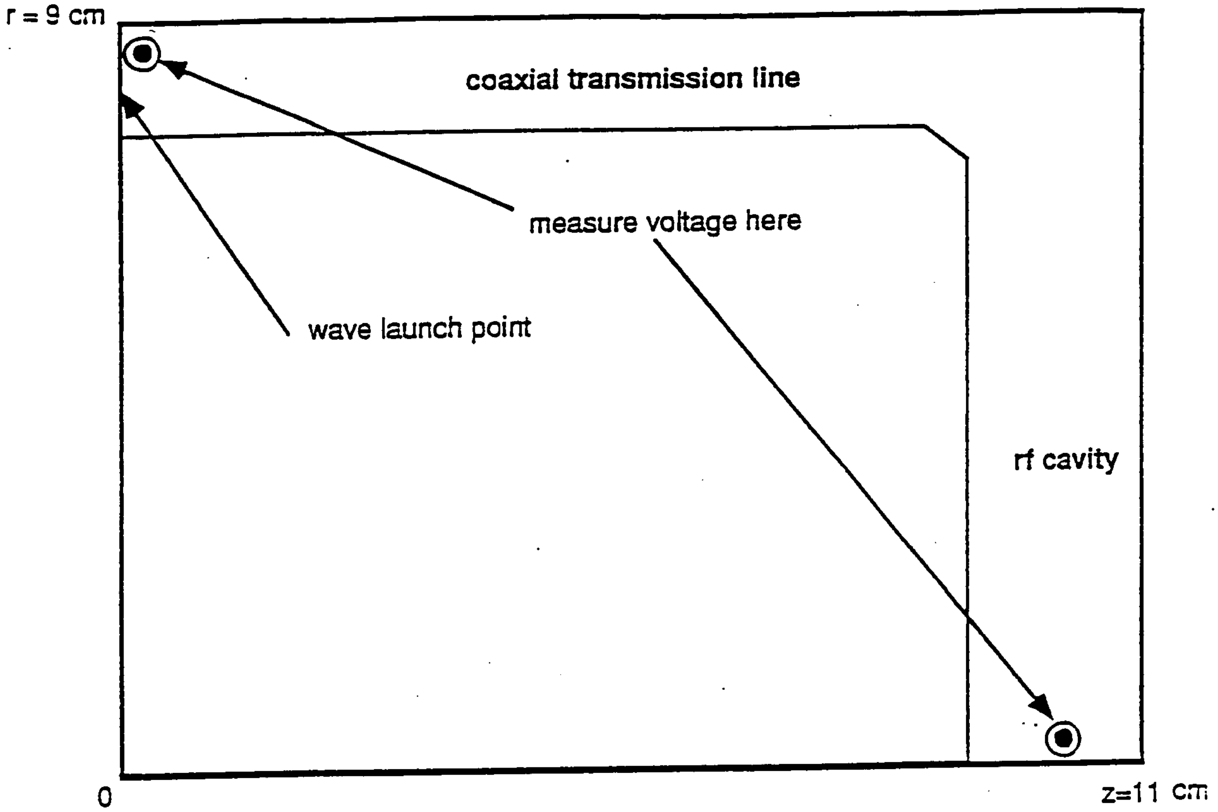

r = 9 cm
coaxial transmission line
measure voltage here
wave launch point
rf cavity
0
z=11 cm

FIGURE 19

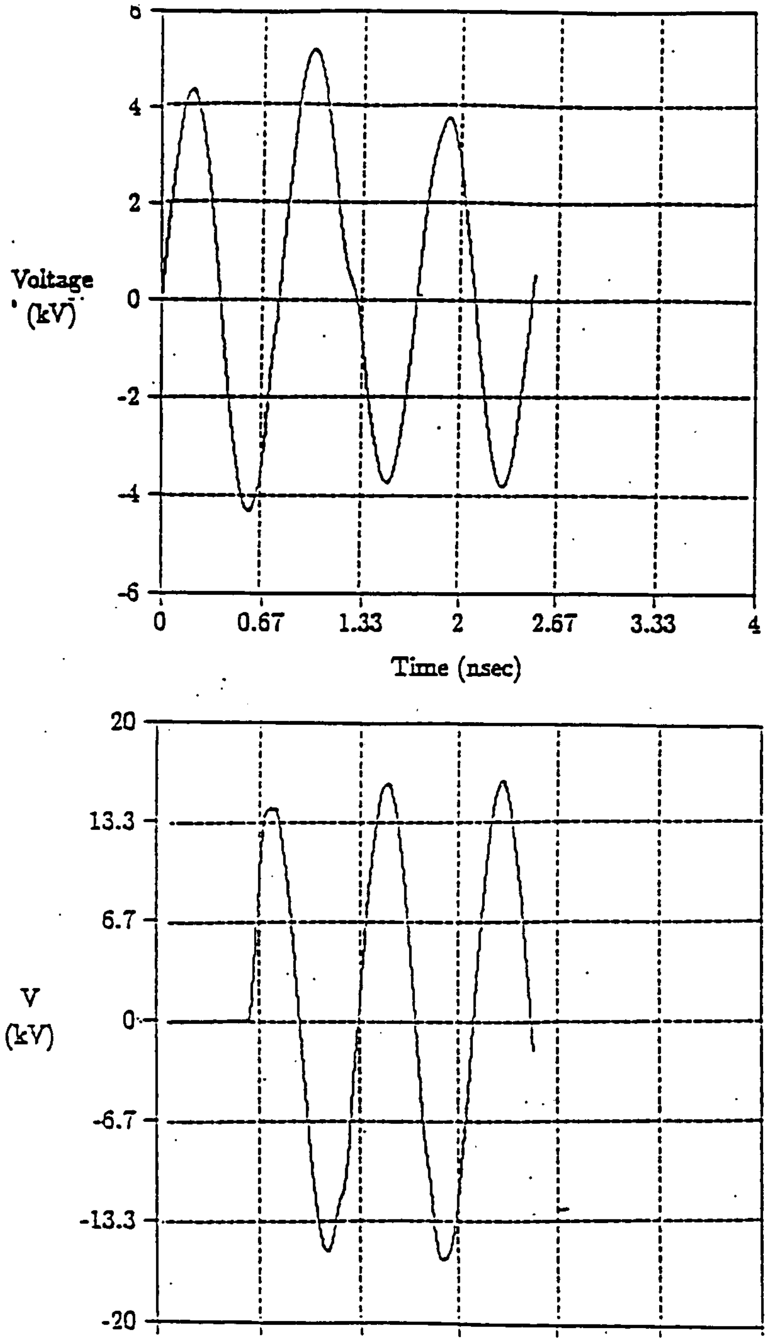

6
4
2
0
-2
-4
-6
Voltage
(kV)
0
0.67
1.33
2
2.67
3.33
4
Time (nsec)
20
13.3
6.7
0
-6.7
-13.3
-20
V
(kV)

FIGURE 20

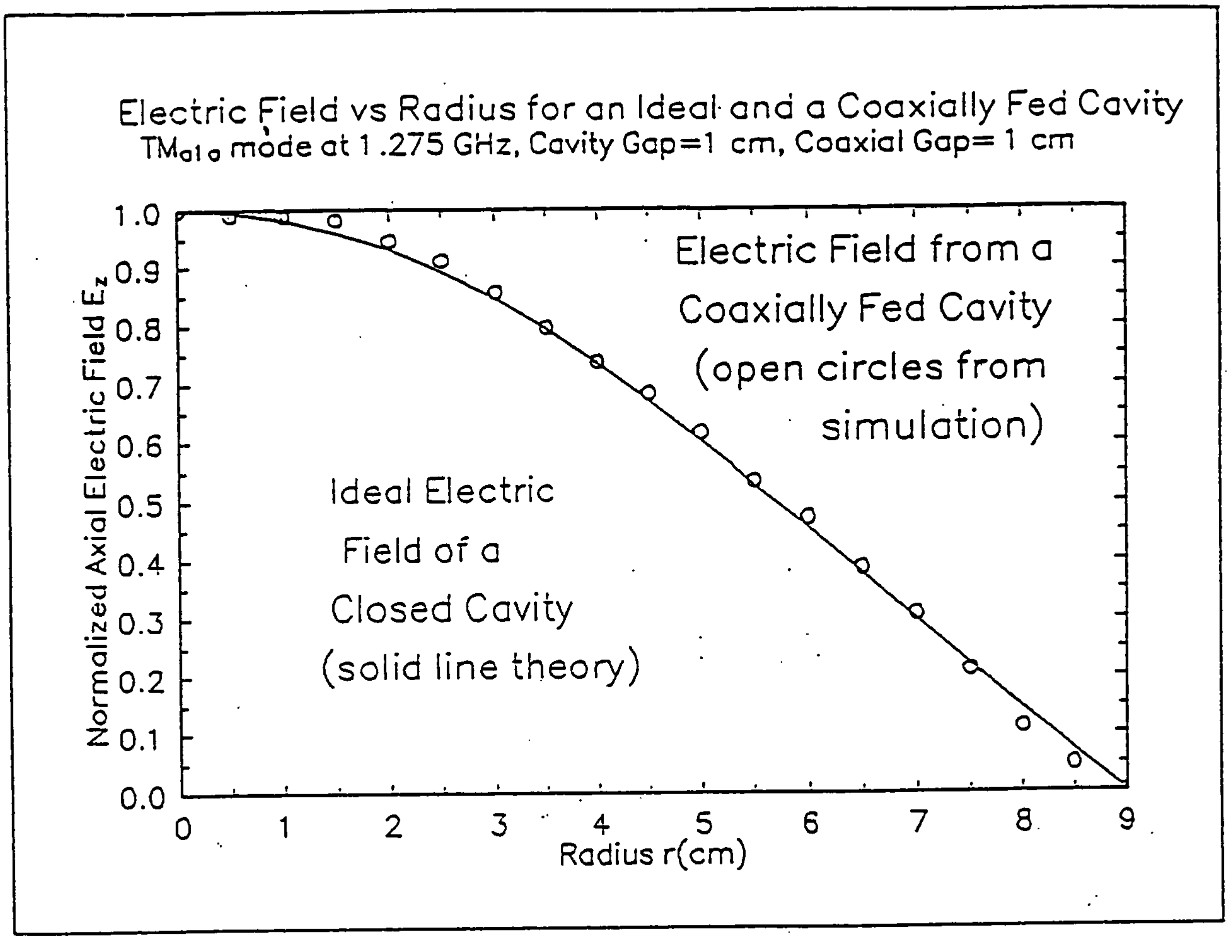

Electric Field vs Radius for an Ideal and a Coaxially Fed Cavity
TM$_{010}$ mode at 1.275 GHz, Cavity Gap=1 cm, Coaxial Gap= 1 cm
Normalized Axial Electric Field E$_z$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
Radius r(cm)
Electric Field from a Coaxially Fed Cavity (open circles from simulation)
Ideal Electric Field of a Closed Cavity (solid line theory)

FIGURE 21

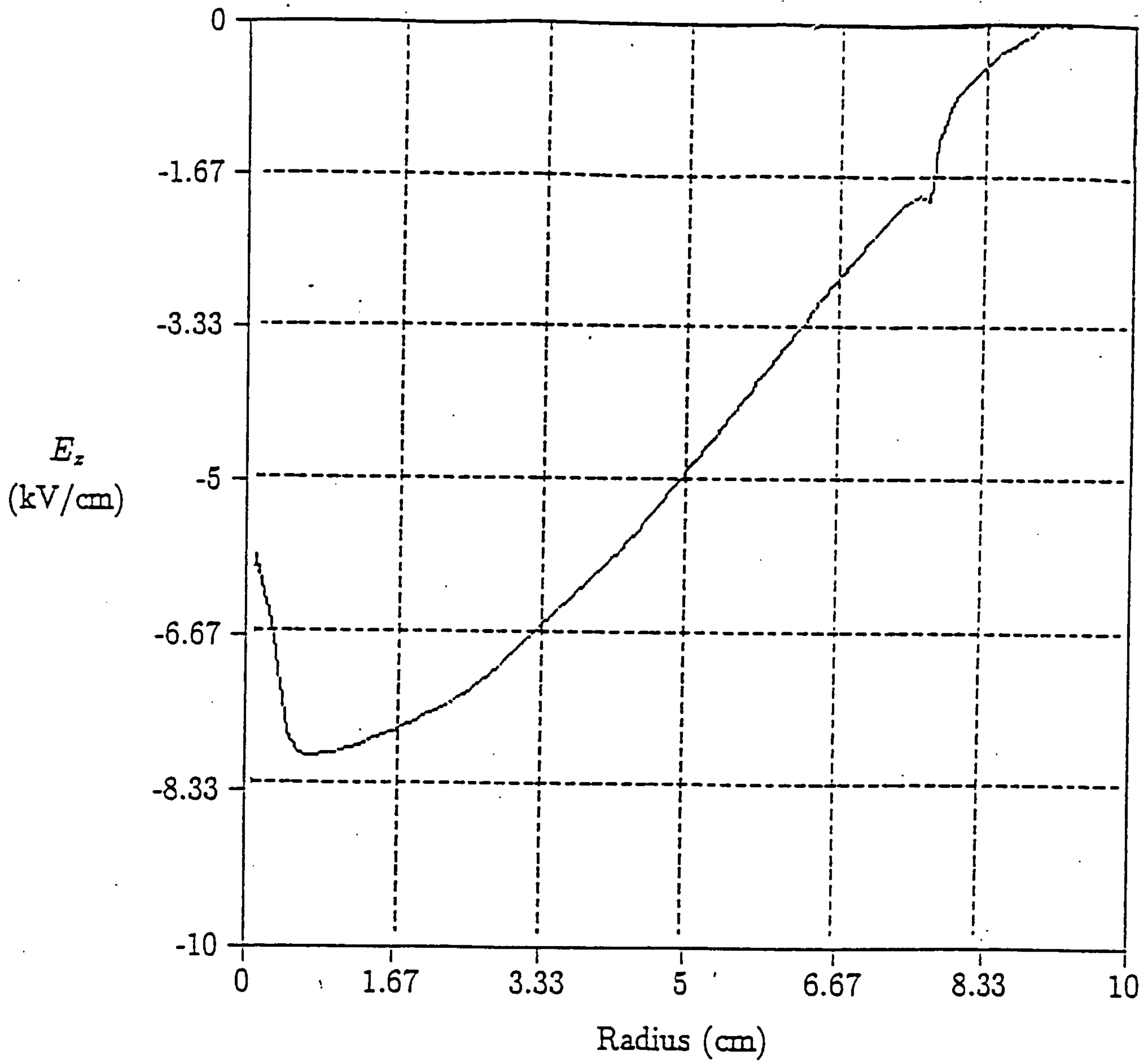


FIGURE 22

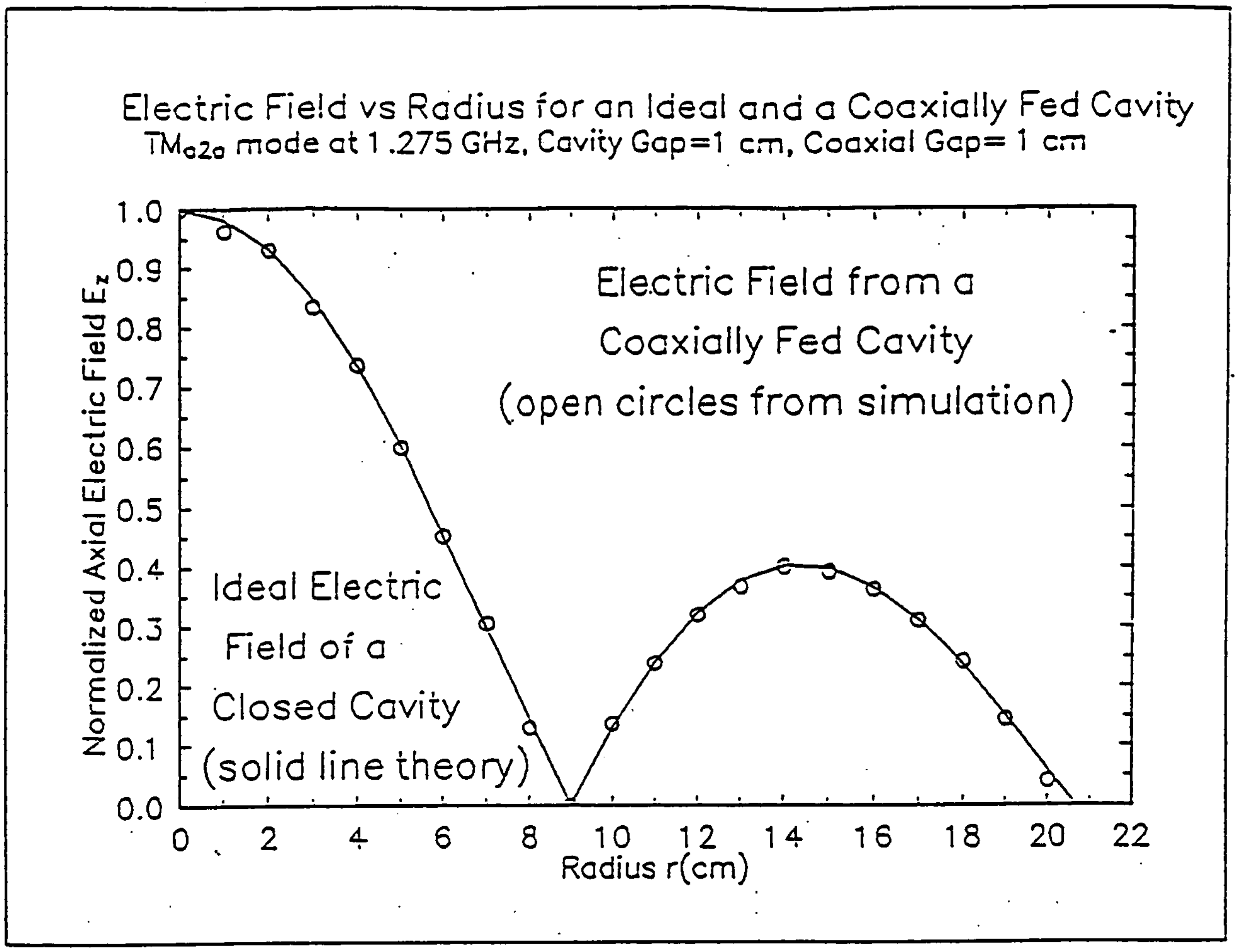

Electric Field vs Radius for an Ideal and a Coaxially Fed Cavity
TM$_{020}$ mode at 1.275 GHz, Cavity Gap=1 cm, Coaxial Gap= 1 cm
Normalized Axial Electric Field E$_z$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
Radius r(cm)
Electric Field from a Coaxially Fed Cavity (open circles from simulation)
Ideal Electric Field of a Closed Cavity (solid line theory)

FIGURE 23

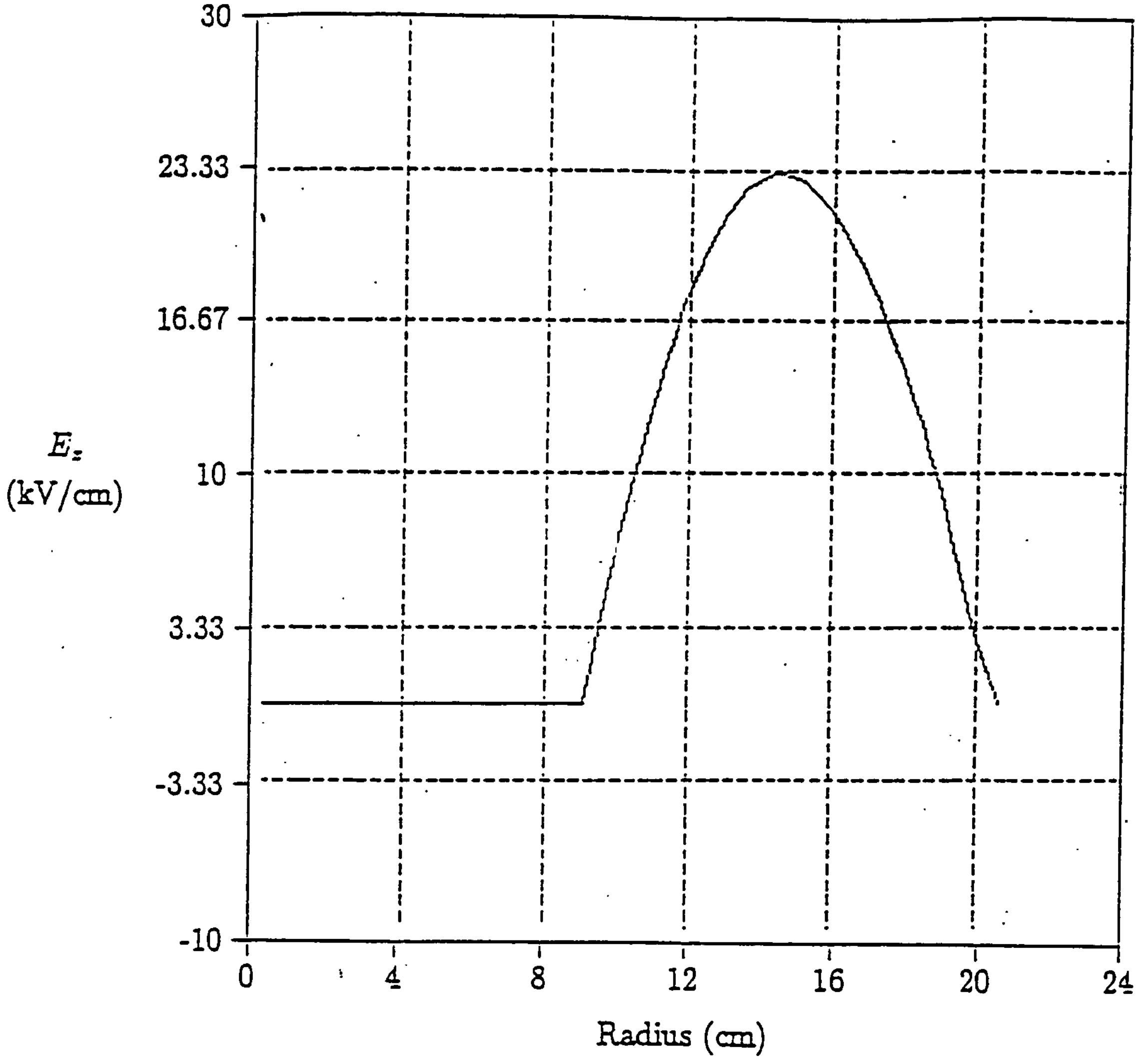


FIGURE 24

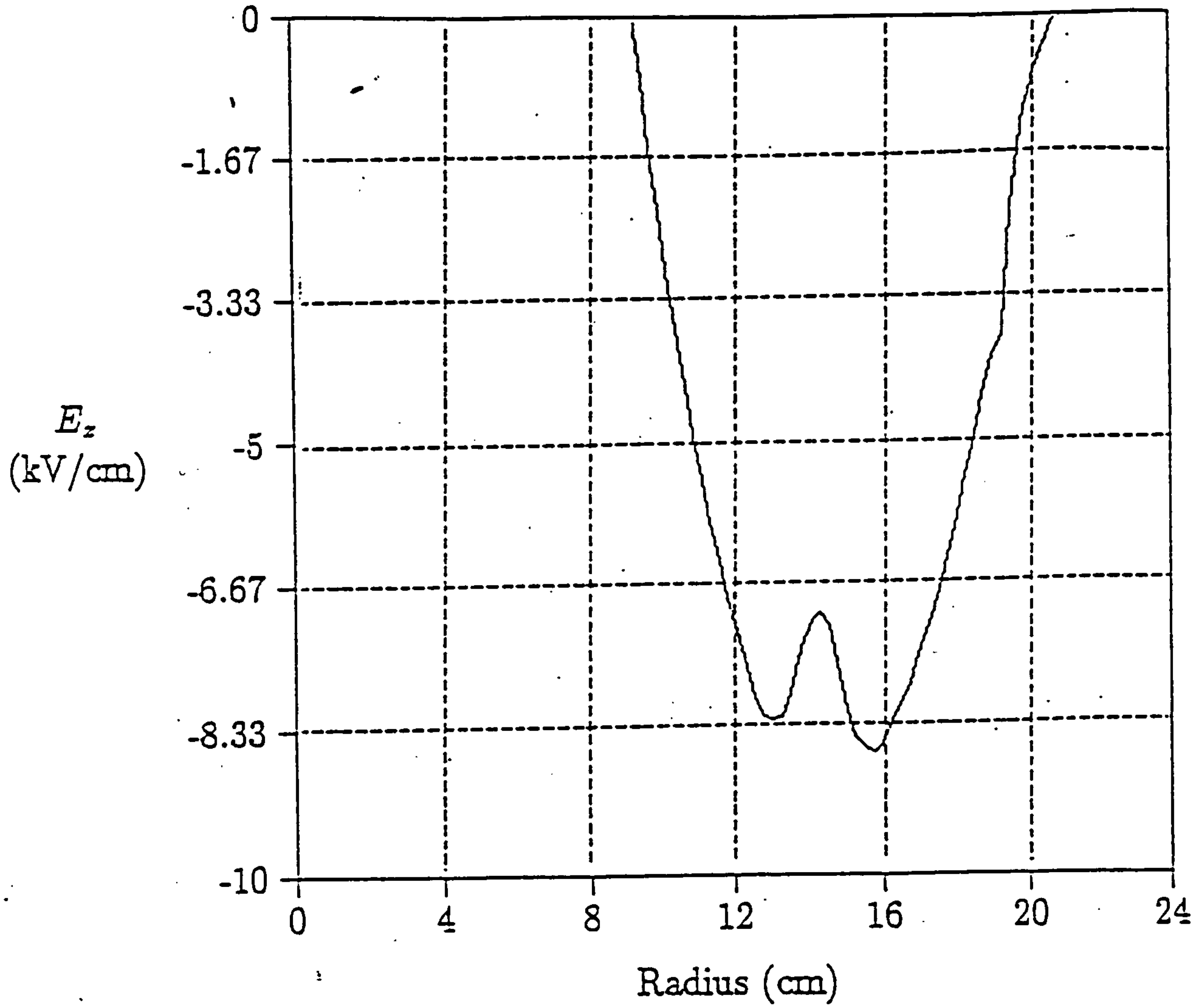
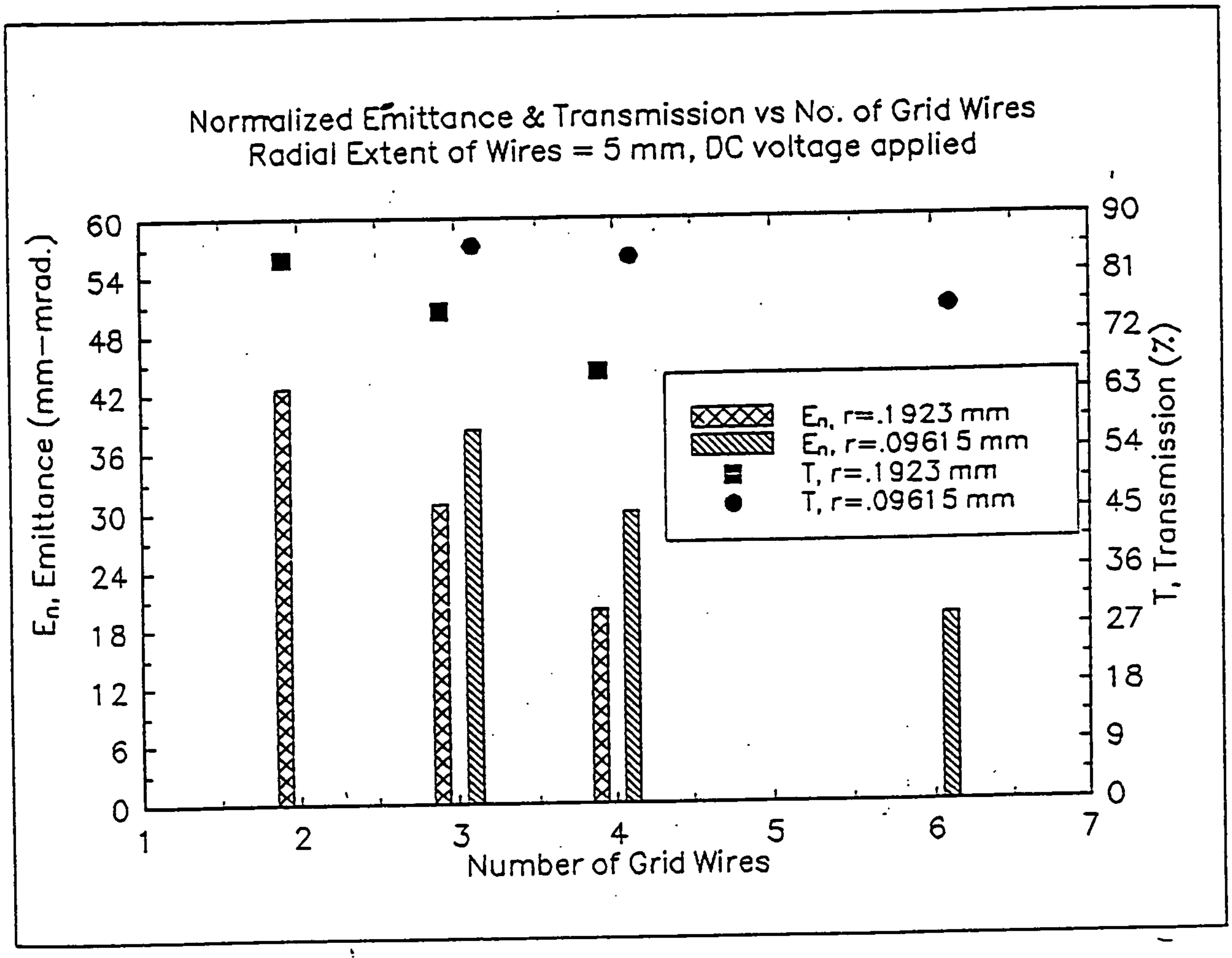


FIGURE 25



Normalized Emittance & Transmission vs No. of Grid Wires
Radial Extent of Wires = 5 mm, DC voltage applied
En, Emittance (mm−mrad.)
60
54
48
42
36
30
24
18
12
6
0
T, Transmission (%)
90
81
72
63
54
45
36
27
18
9
0
1
2
3
4
5
6
7
Number of Grid Wires
En, r=.1923 mm
En, r=.09615 mm
T, r=.1923 mm
T, r=.09615 mm

FIGURE 26

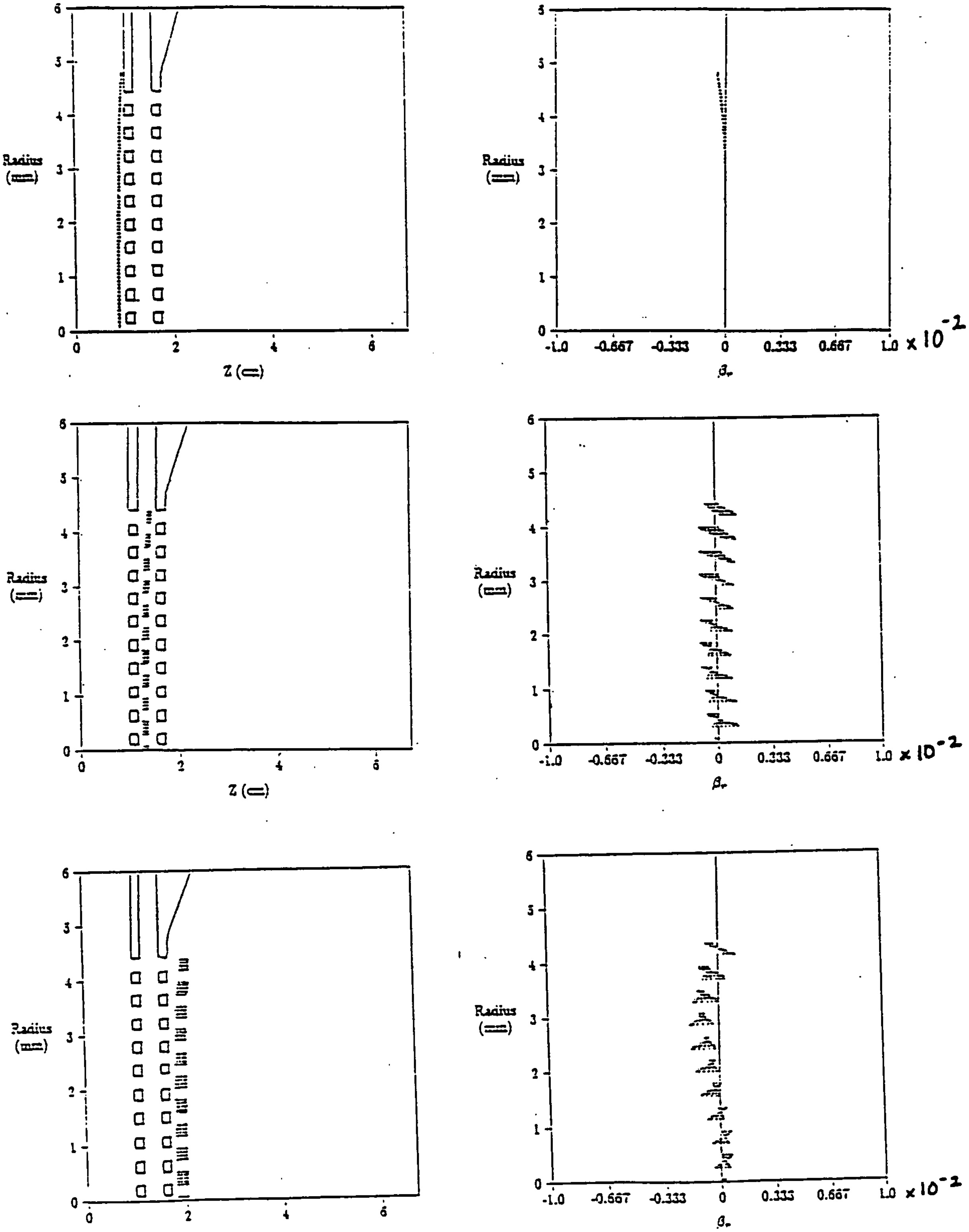


FIGURE 27

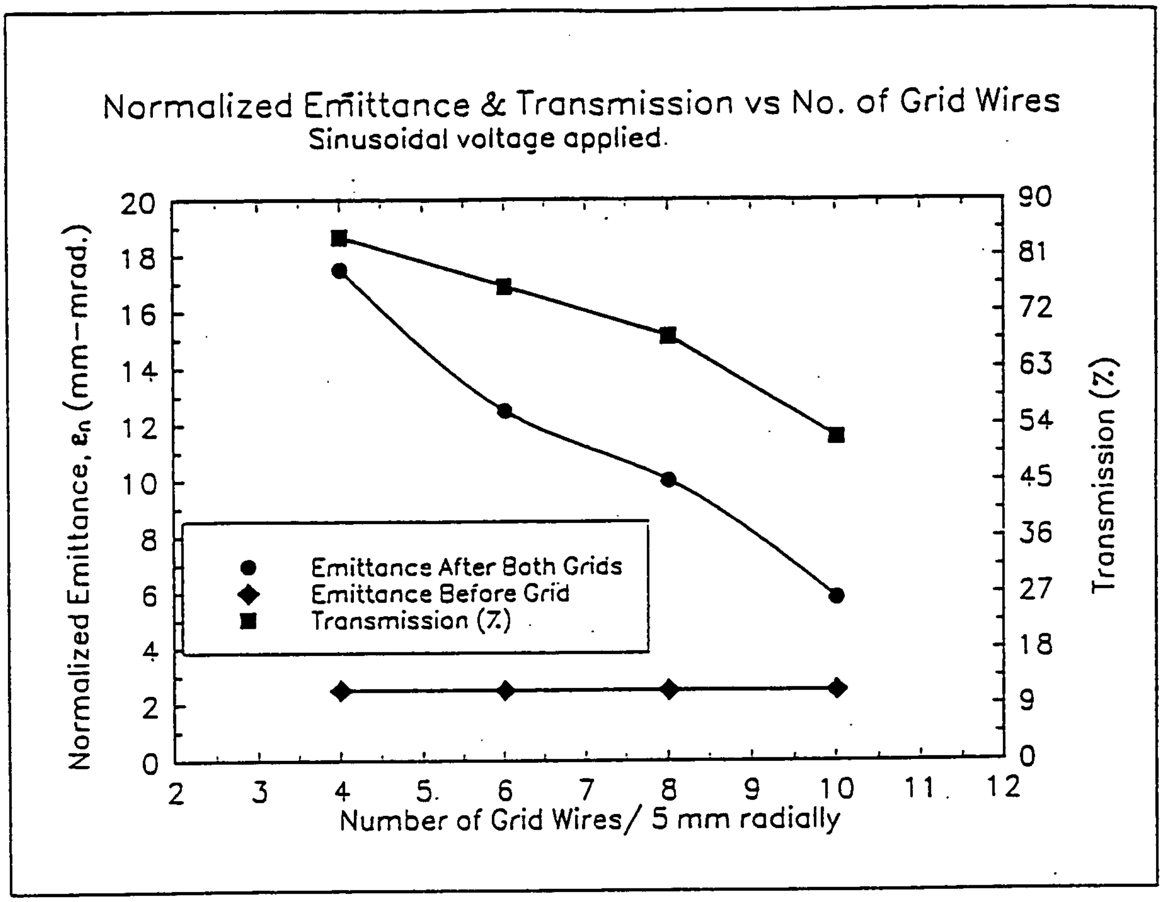

Normalized Emittance & Transmission vs No. of Grid Wires
Sinusoidal voltage applied.
Normalized Emittance, ε_n (mm-mrad.)
20
18
16
14
12
10
8
6
4
2
0
90
81
72
63
54
45
36
27
18
9
0
Transmission (%)
2
3
4
5
6
7
8
9
10
11
12
Number of Grid Wires/ 5 mm radially
● Emittance After Both Grids
◆ Emittance Before Grid
■ Transmission (%)

FIGURE 28

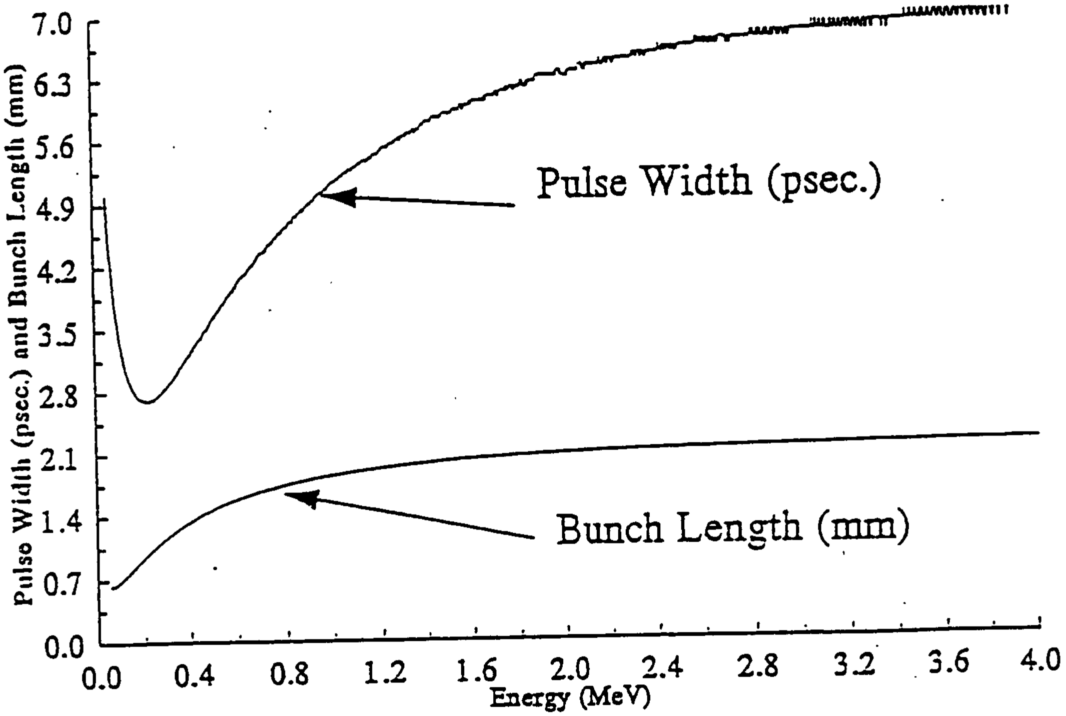

7.0
6.3
5.6
4.9
4.2
3.5
2.8
2.1
1.4
0.7
0.0
Pulse Width (psec.) and Bunch Length (mm)
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
Energy (MeV)
Pulse Width (psec.)
Bunch Length (mm)

FIGURE 29

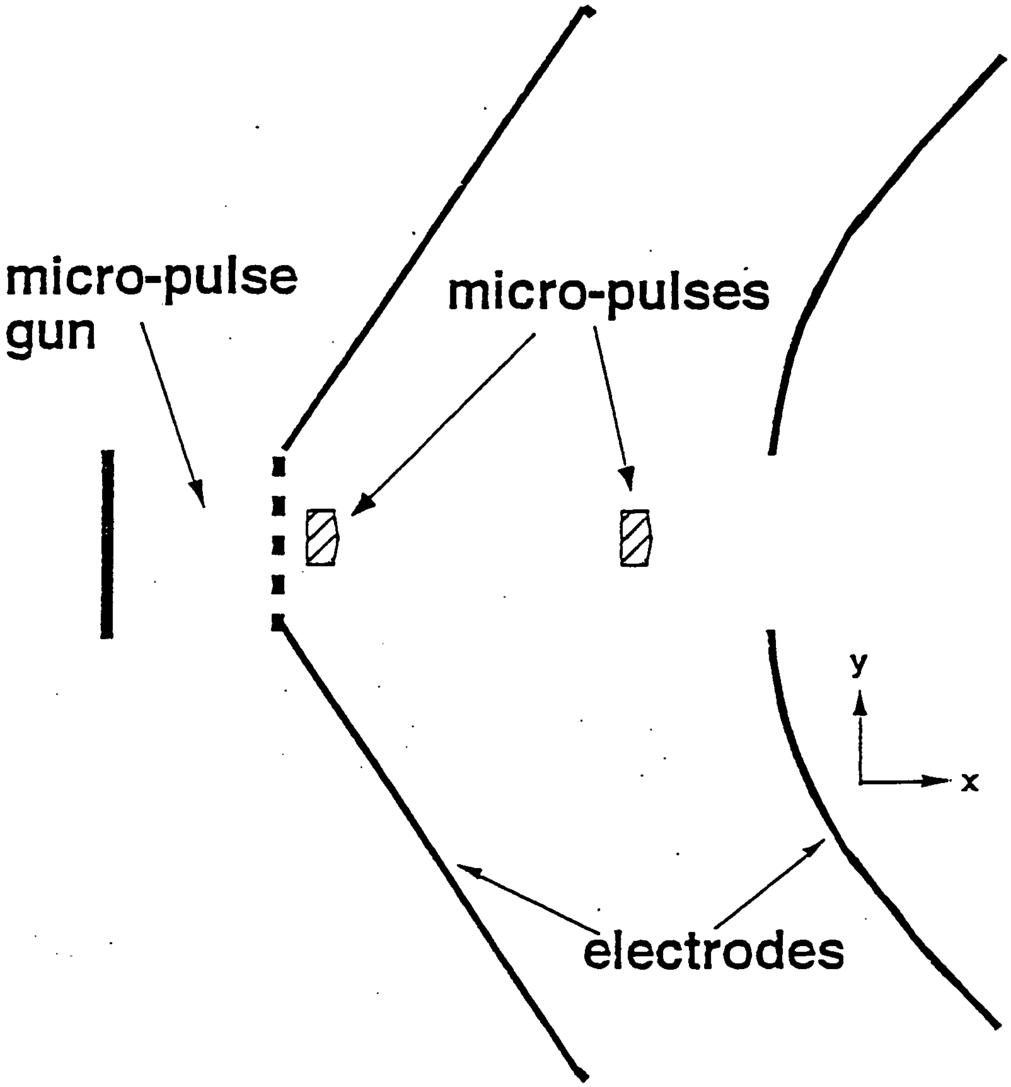
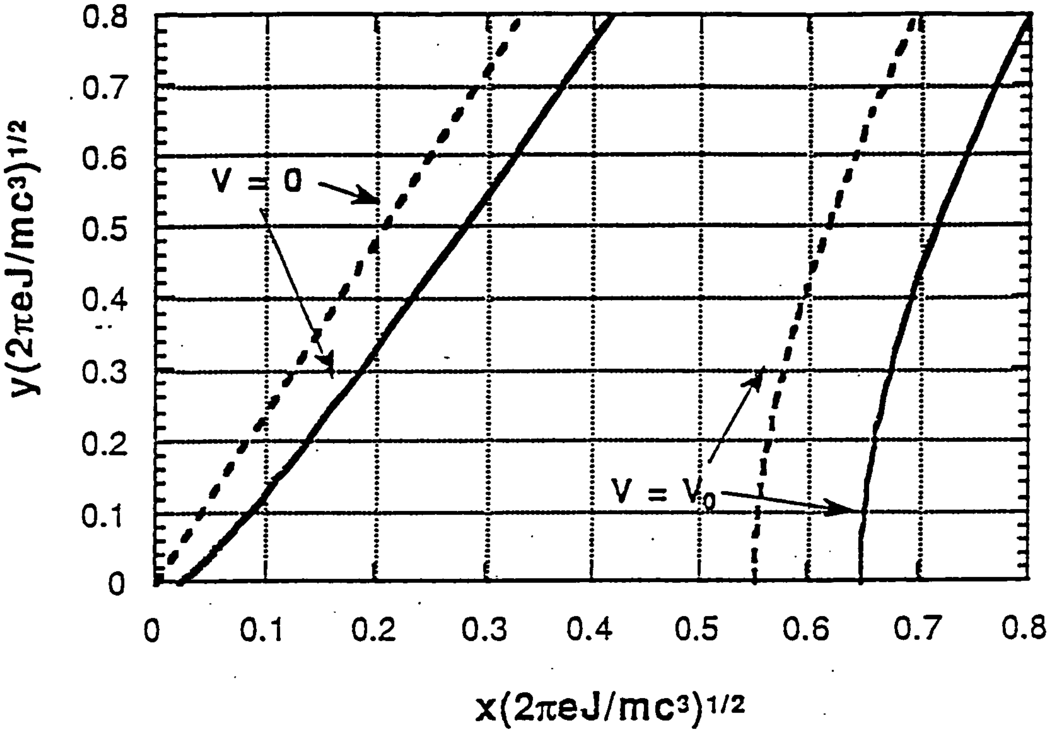


FIGURE 30



0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y(2πeJ/mc³)¹ᐟ²
V = 0
V = V₀
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x(2πeJ/mc³)¹ᐟ²

FIGURE 31

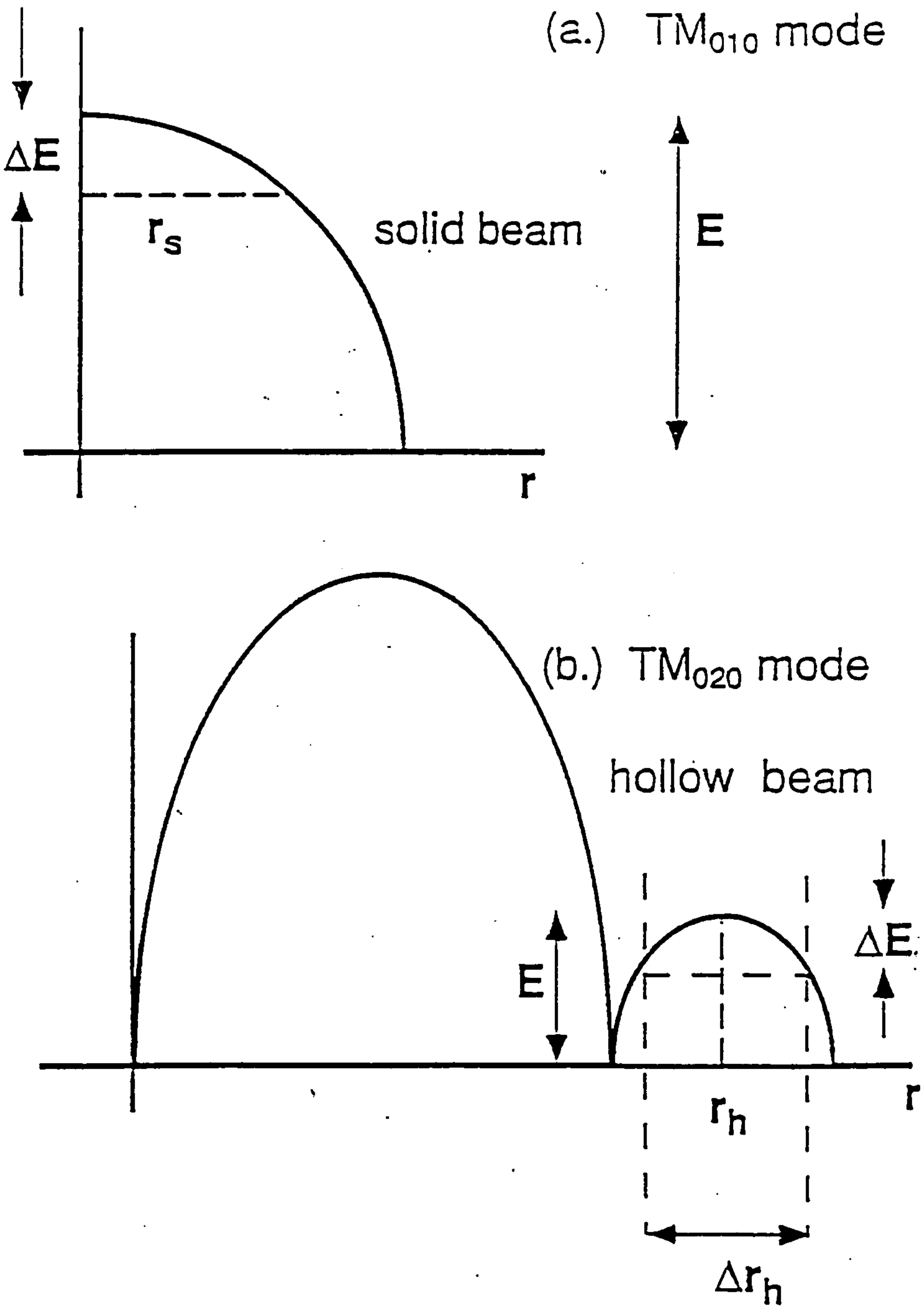

(a.) TM_{010} mode
ΔE
r_s
solid beam
E
r
(b.) TM_{020} mode
hollow beam
E
ΔE
r_h
r
Δr_h

FIGURE 32

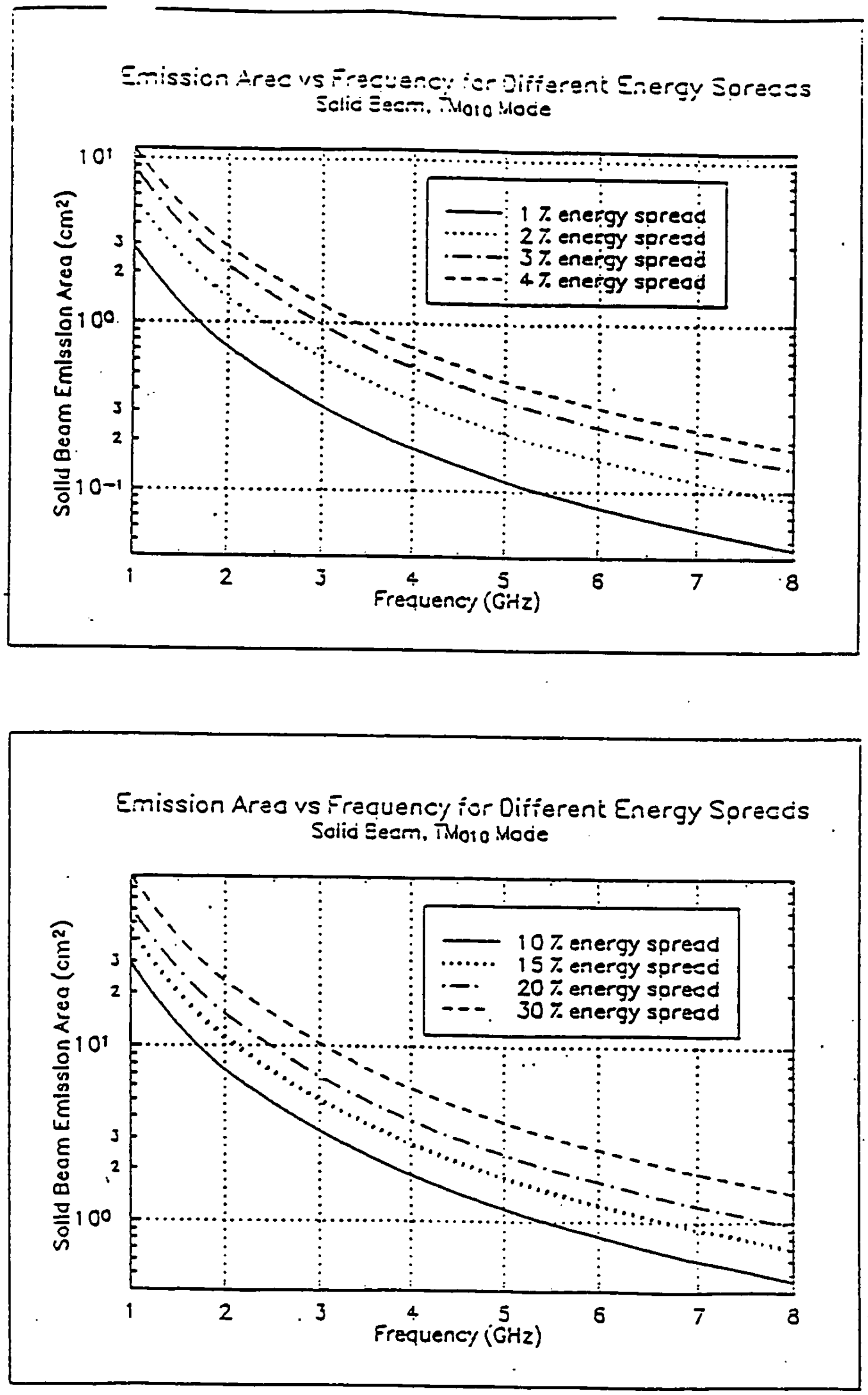

Emission Area vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode
Solid Beam Emission Area (cm²)
10¹
3
2
10⁰
3
2
10⁻¹
1
2
3
4
5
6
7
8
Frequency (GHz)
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Emission Area vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode
Solid Beam Emission Area (cm²)
3
2
10¹
3
2
10⁰
1
2
3
4
5
6
7
8
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 33

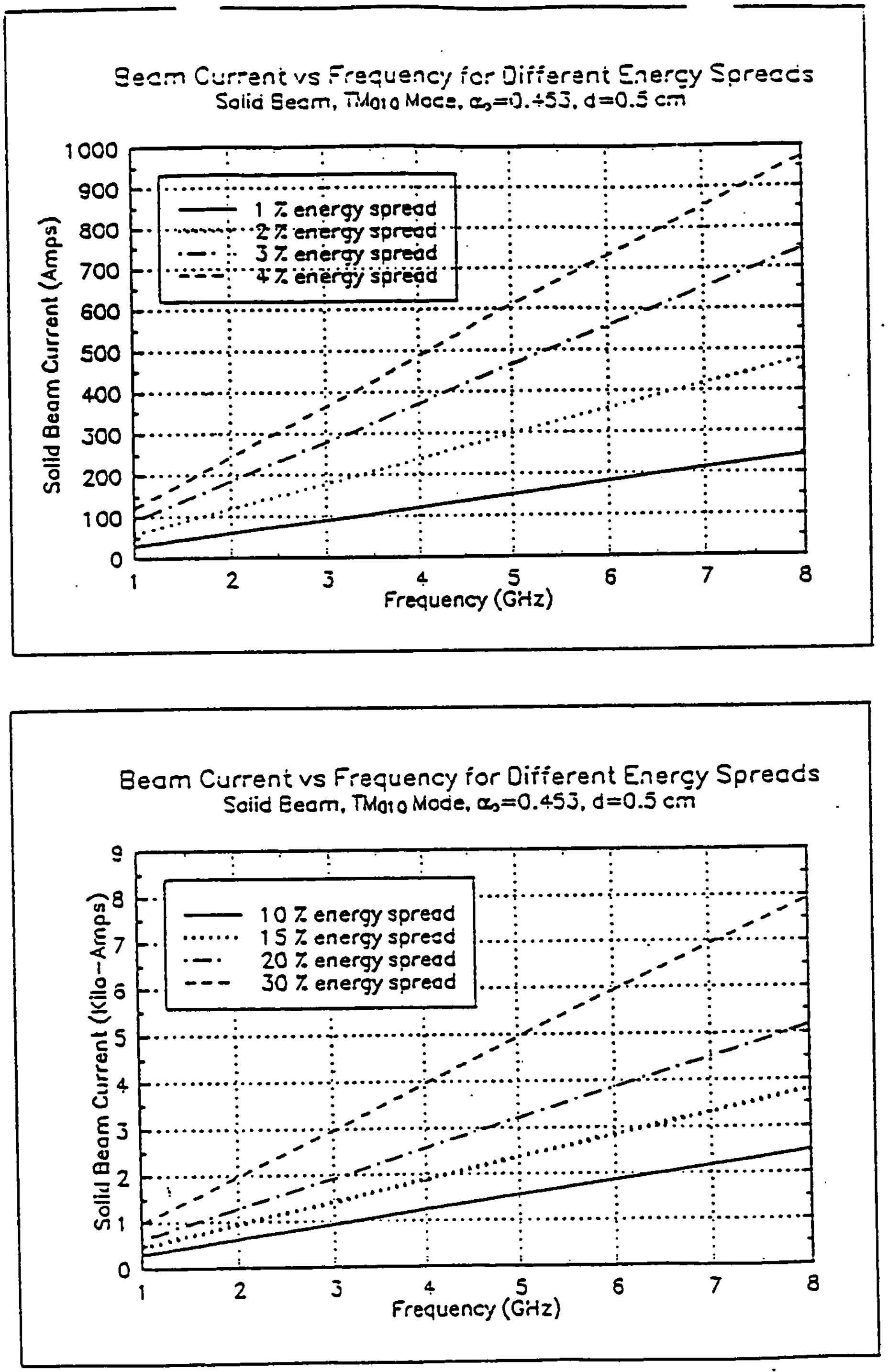

Beam Current vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode, α0=0.453, d=0.5 cm
Solid Beam Current (Amps)
1000
900
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
Frequency (GHz)
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Beam Current vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode, α0=0.453, d=0.5 cm
Solid Beam Current (Kilo-Amps)
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 34

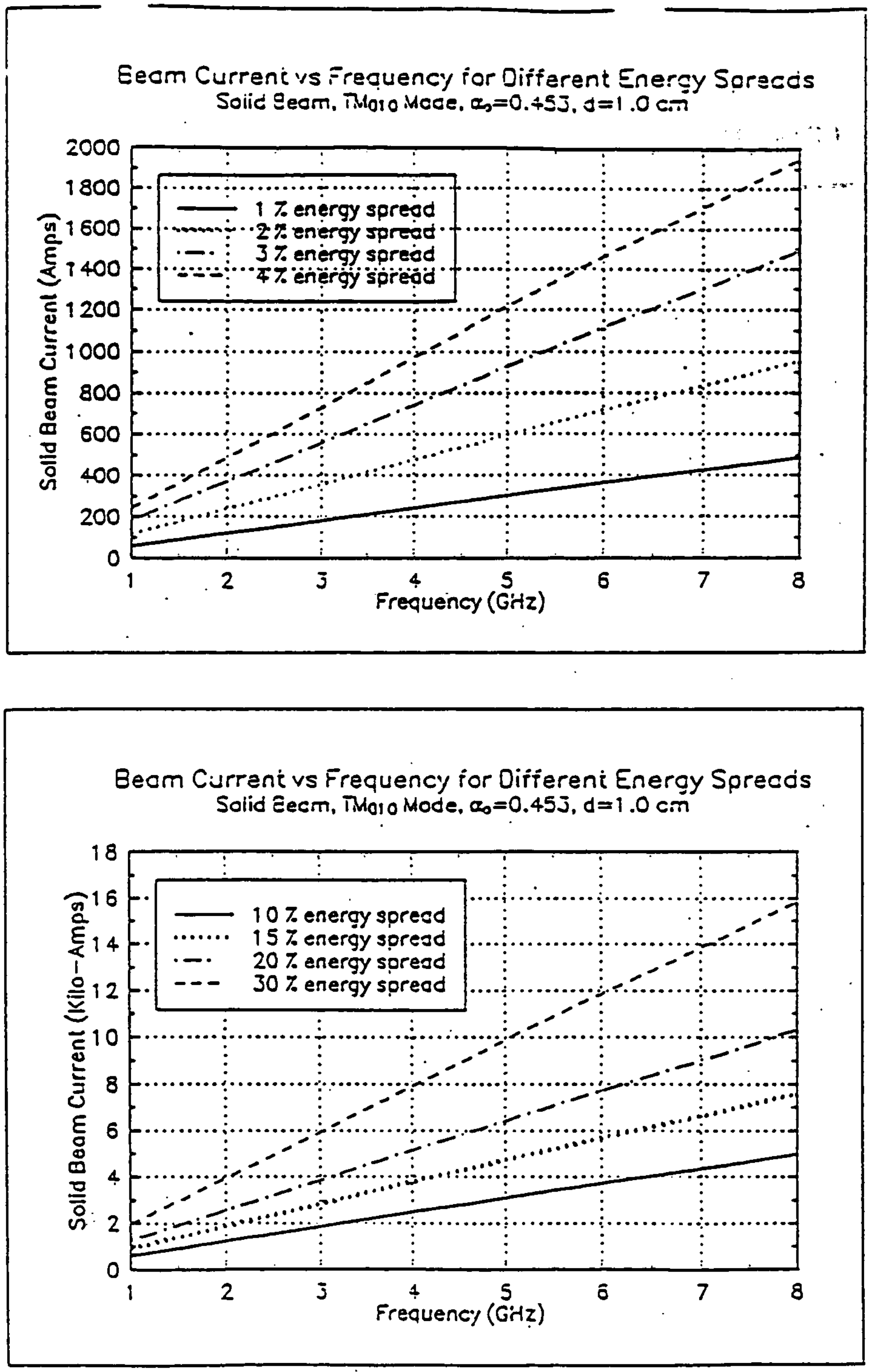

Beam Current vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode, α₀=0.453, d=1.0 cm
Solid Beam Current (Amps)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
1
2
3
4
5
6
7
8
Frequency (GHz)
Beam Current vs Frequency for Different Energy Spreads
Solid Beam, TM010 Mode, α₀=0.453, d=1.0 cm
Solid Beam Current (Kilo-Amps)
0
2
4
6
8
10
12
14
16
18
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread
1
2
3
4
5
6
7
8
Frequency (GHz)

FIGURE 35

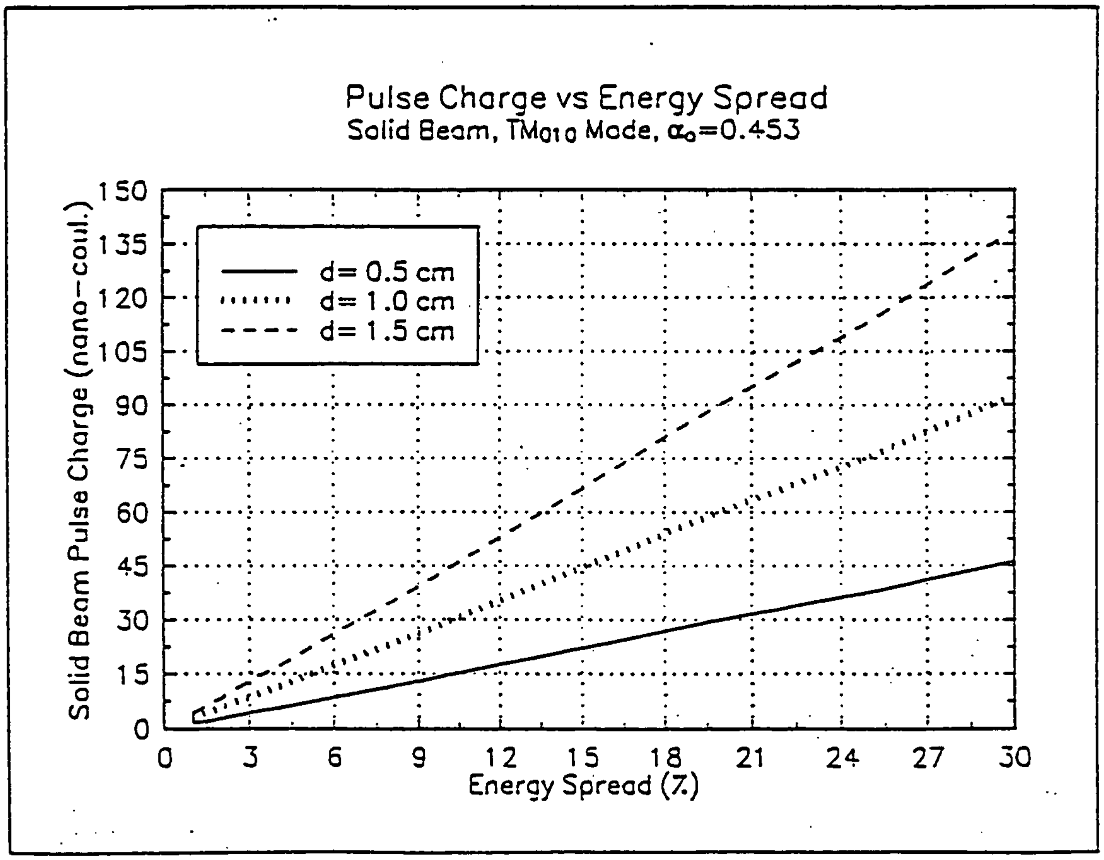

Pulse Charge vs Energy Spread
Solid Beam, TM_{010} Mode, α_o=0.453
Solid Beam Pulse Charge (nano-coul.)
150
135
120
105
90
75
60
45
30
15
0
0
3
6
9
12
15
18
21
24
27
30
Energy Spread (%)
d= 0.5 cm
d= 1.0 cm
d= 1.5 cm

FIGURE 36

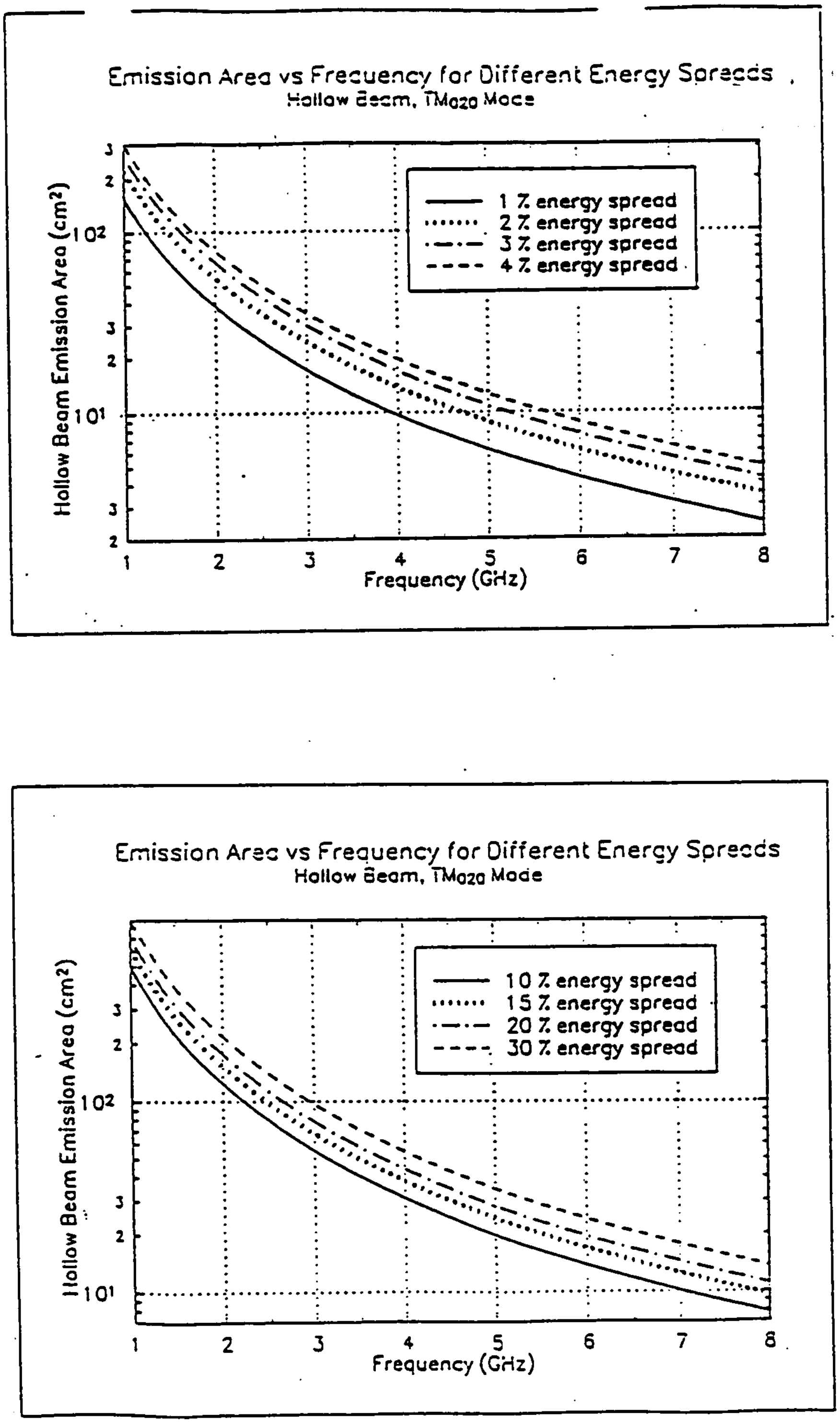
Emission Area vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode
Hollow Beam Emission Area (cm²)
Frequency (GHz)
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
10²
10¹
3
2
1
2
3
4
5
6
7
8
Emission Area vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode
Hollow Beam Emission Area (cm²)
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread
10²
10¹
3
2
1
2
3
4
5
6
7
8

FIGURE 37

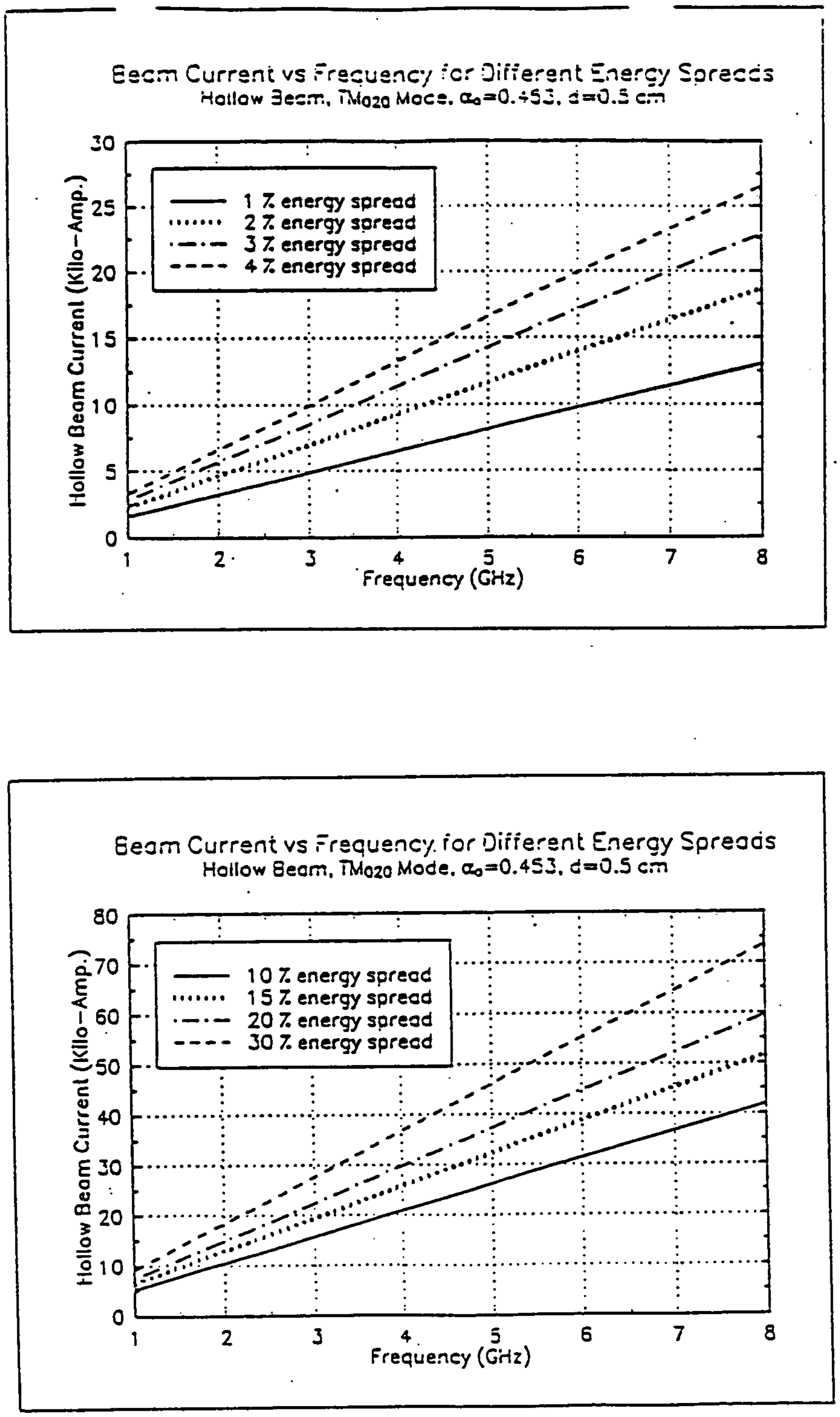
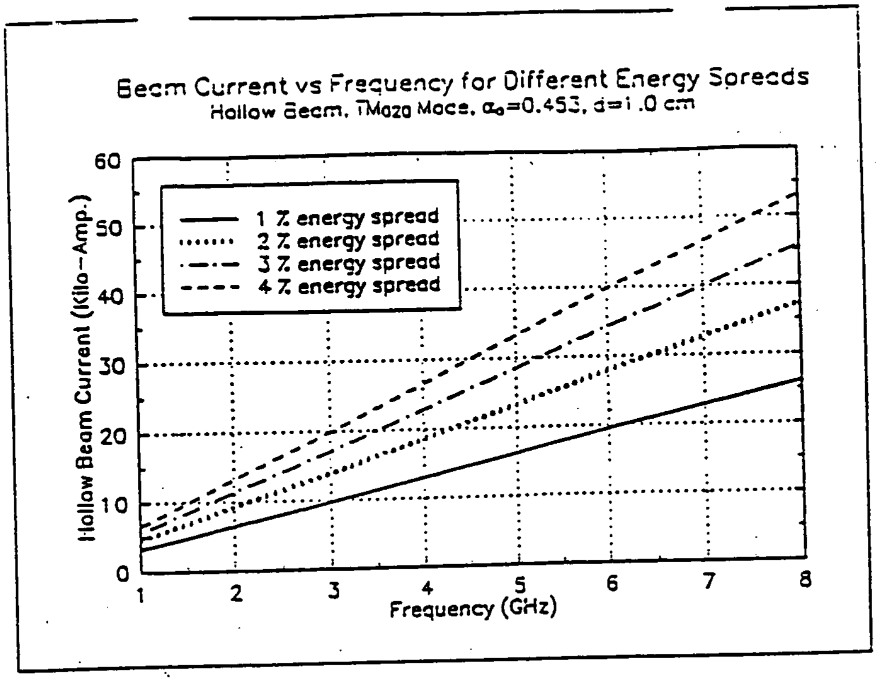

Beam Current vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode, α0=0.453, d=0.5 cm
Hollow Beam Current (Kilo-Amp.)
Frequency (GHz)
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Beam Current vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode, α0=0.453, d=0.5 cm
Hollow Beam Current (Kilo-Amp.)
Frequency (GHz)
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 38


Beam Current vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode, α0=0.453, d=1.0 cm
Hollow Beam Current (Kilo-Amp.)
Frequency (GHz)
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread

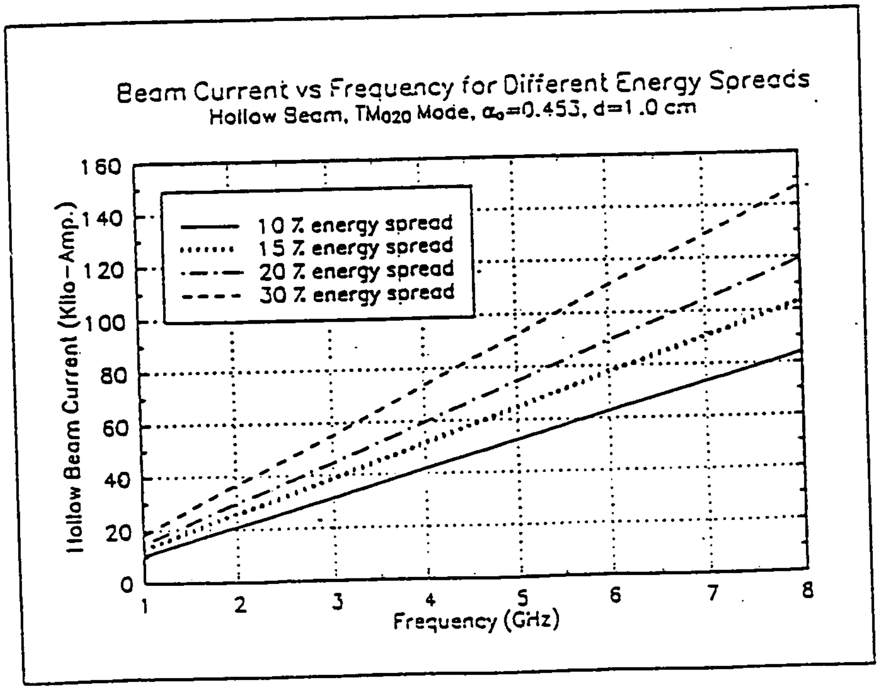

Beam Current vs Frequency for Different Energy Spreads
Hollow Beam, TM020 Mode, α0=0.453, d=1.0 cm
Hollow Beam Current (Kilo-Amp.)
Frequency (GHz)
0
20
40
60
80
100
120
140
160
1
2
3
4
5
6
7
8
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 39

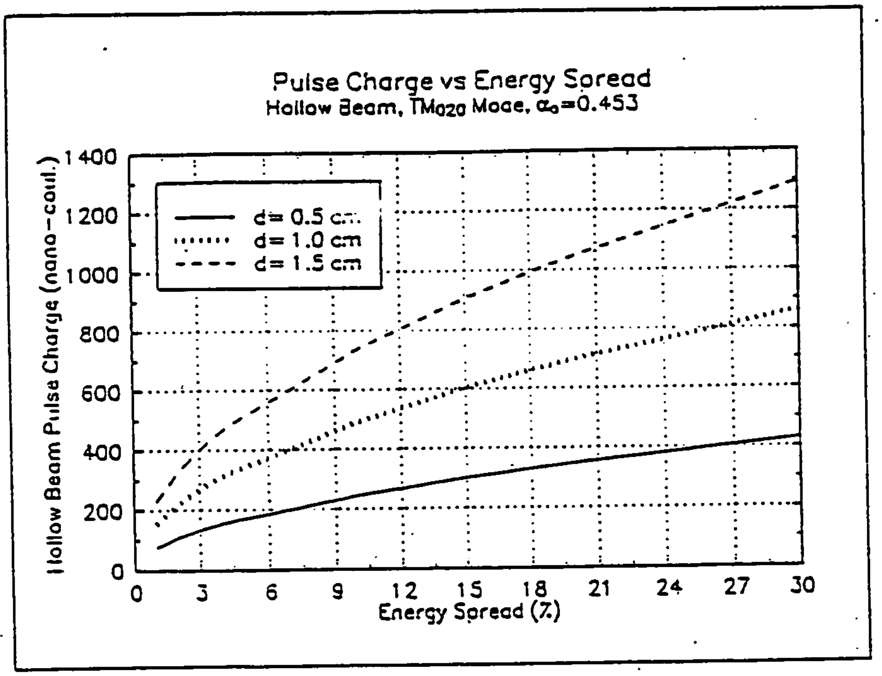

Pulse Charge vs Energy Spread
Hollow Beam, TM020 Mode, α_0=0.453
Hollow Beam Pulse Charge (nano-coul.)
1400
1200
1000
800
600
400
200
0
0
3
6
9
12
15
18
21
24
27
30
Energy Spread (%)
d= 0.5 cm
d= 1.0 cm
d= 1.5 cm

FIGURE 40

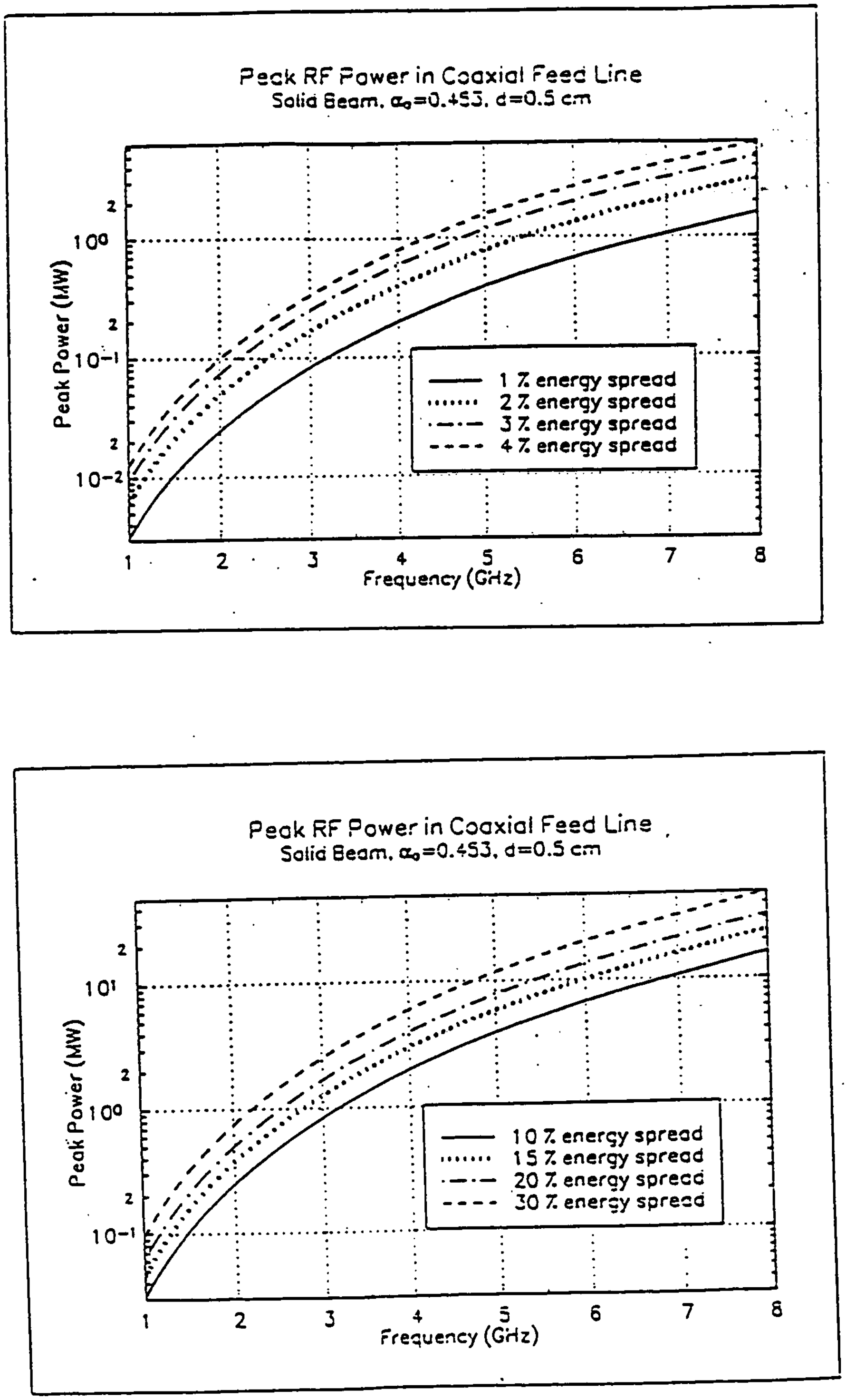
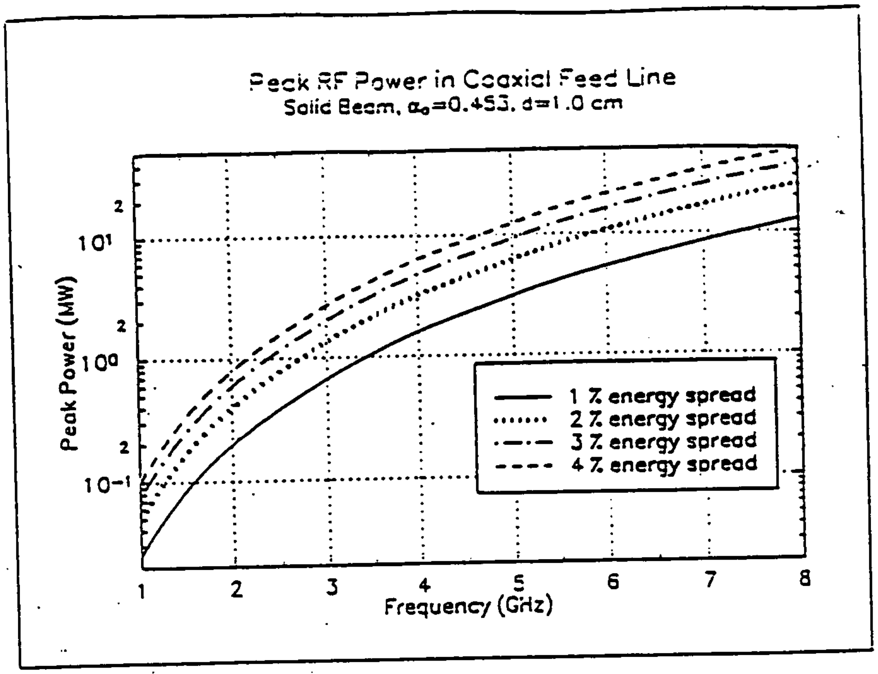

Peak RF Power in Coaxial Feed Line
Solid Beam, α_0=0.453, d=0.5 cm
Peak Power (MW)
10^{-2}
2
10^{-1}
2
10^{0}
2
1
2
3
4
5
6
7
8
Frequency (GHz)
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Peak RF Power in Coaxial Feed Line
Solid Beam, α_0=0.453, d=0.5 cm
Peak Power (MW)
10^{-1}
2
10^{0}
2
10^{1}
2
1
2
3
4
5
6
7
8
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 41


Peak RF Power in Coaxial Feed Line
Solid Beam, α_o=0.453, d=1.0 cm
Peak Power (MW)
10⁻¹
2
10⁰
2
10¹
2
1
2
3
4
5
6
7
8
Frequency (GHz)
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread

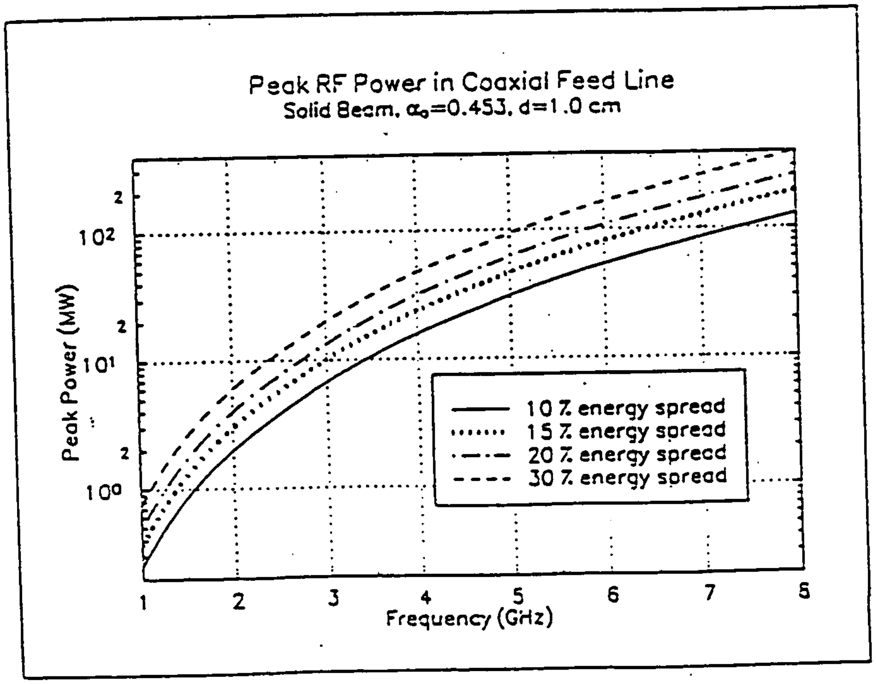

Peak RF Power in Coaxial Feed Line
Solid Beam, α_o=0.453, d=1.0 cm
Peak Power (MW)
10⁰
2
10¹
2
10²
2
1
2
3
4
5
6
7
8
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 42

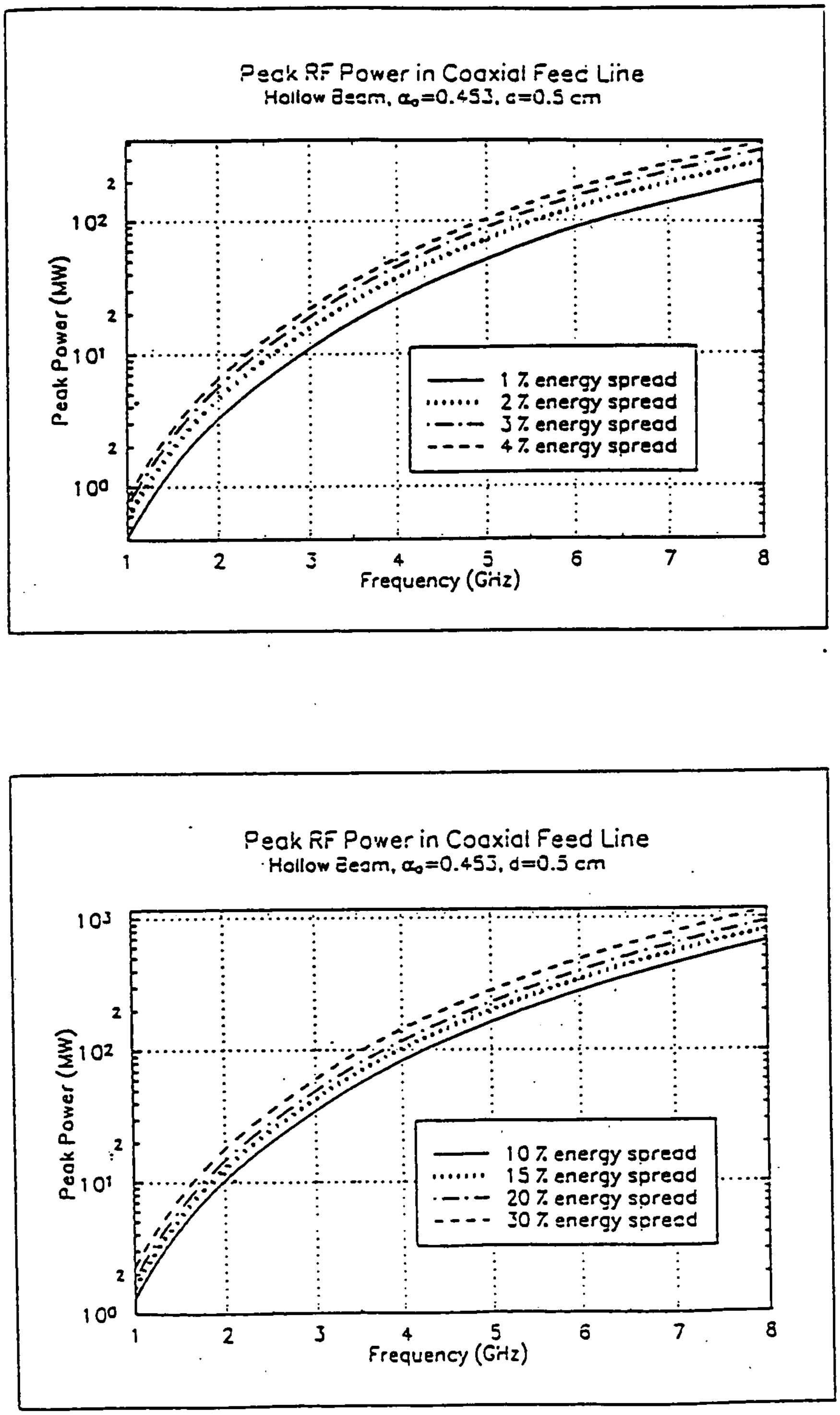

Peak RF Power in Coaxial Feed Line
Hollow Beam, α_0=0.453, c=0.5 cm
Peak Power (MW)
10^0
10^1
10^2
2
Frequency (GHz)
1
2
3
4
5
6
7
8
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Peak RF Power in Coaxial Feed Line
Hollow Beam, α_0=0.453, d=0.5 cm
Peak Power (MW)
10^0
10^1
10^2
10^3
2
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 43

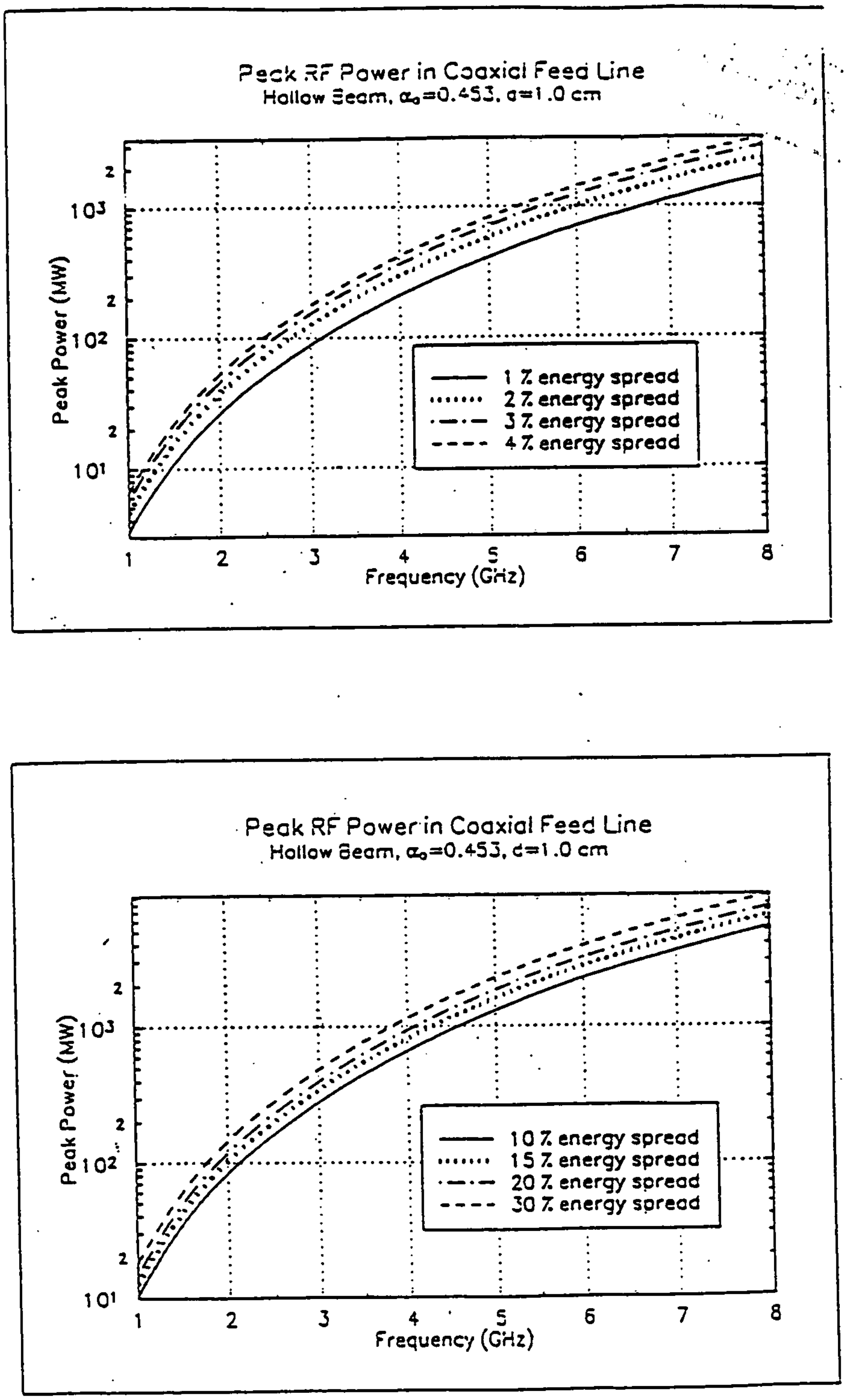

Peak RF Power in Coaxial Feed Line
Hollow Beam, α_0=0.453, d=1.0 cm
Peak Power (MW)
Frequency (GHz)
10¹
10²
10³
2
1
2
3
4
5
6
7
8
1 % energy spread
2 % energy spread
3 % energy spread
4 % energy spread
Peak RF Power in Coaxial Feed Line
Hollow Beam, α_0=0.453, d=1.0 cm
Peak Power (MW)
Frequency (GHz)
10 % energy spread
15 % energy spread
20 % energy spread
30 % energy spread

FIGURE 44

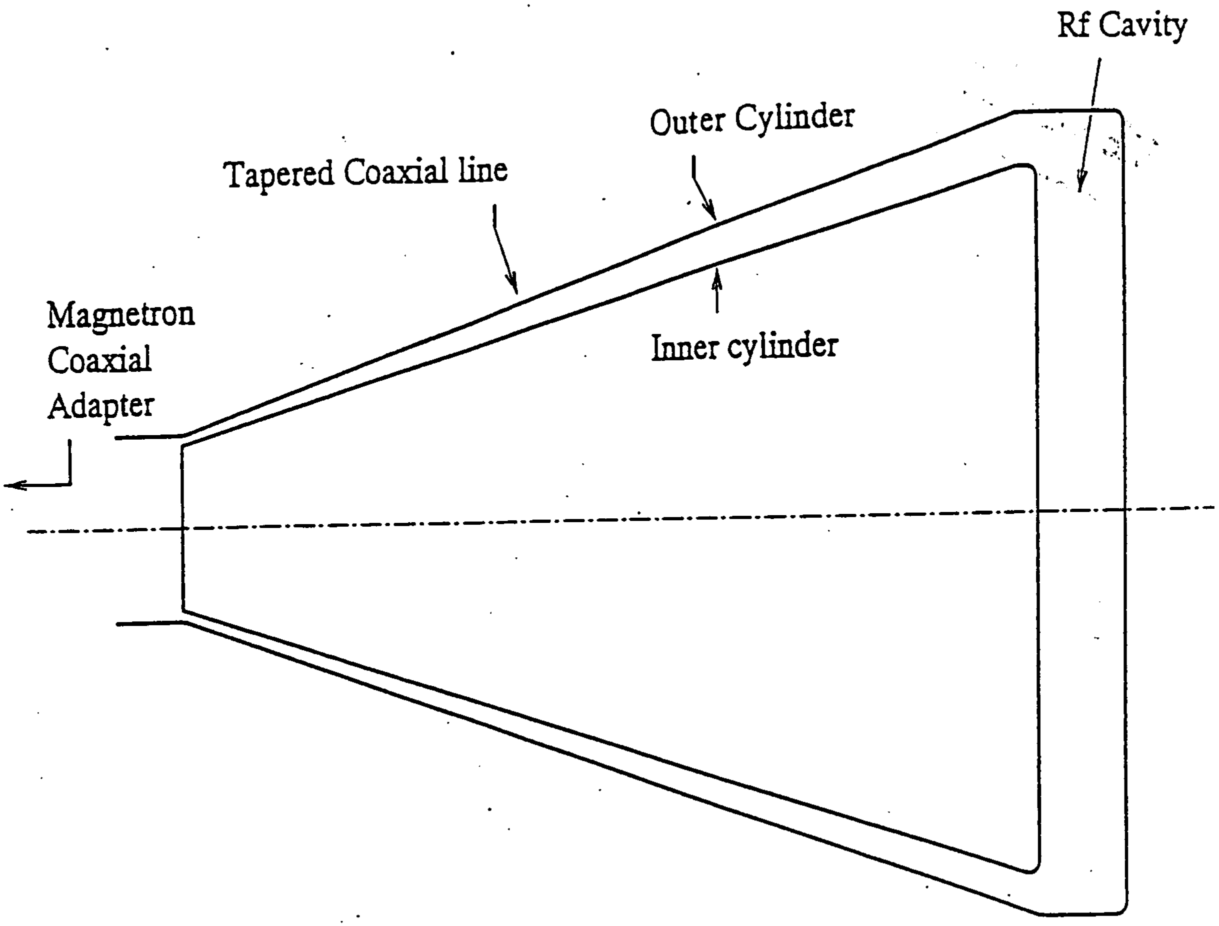

Rf Cavity
Outer Cylinder
Tapered Coaxial line
Magnetron
Coaxial
Adapter
Inner cylinder

FIGURE 45

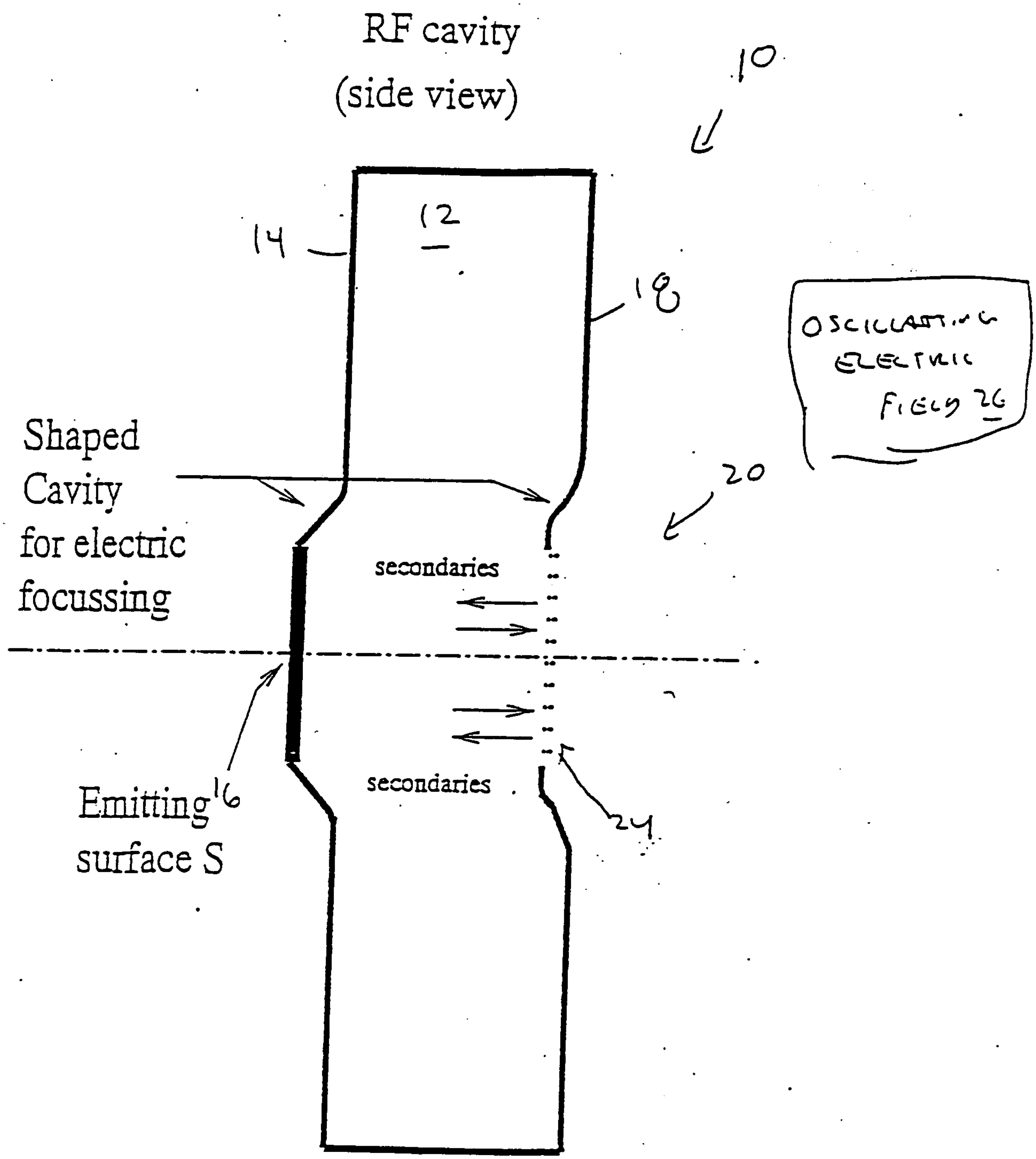

RF cavity
(side view)
10
12
14
18
OSCILLATING ELECTRIC FIELD 26
Shaped Cavity for electric focussing
20
secondaries
secondaries
Emitting 16 surface S
24

FIGURE 46